# VIRGINIA PRODUCTIVITY CENTER



The Study of

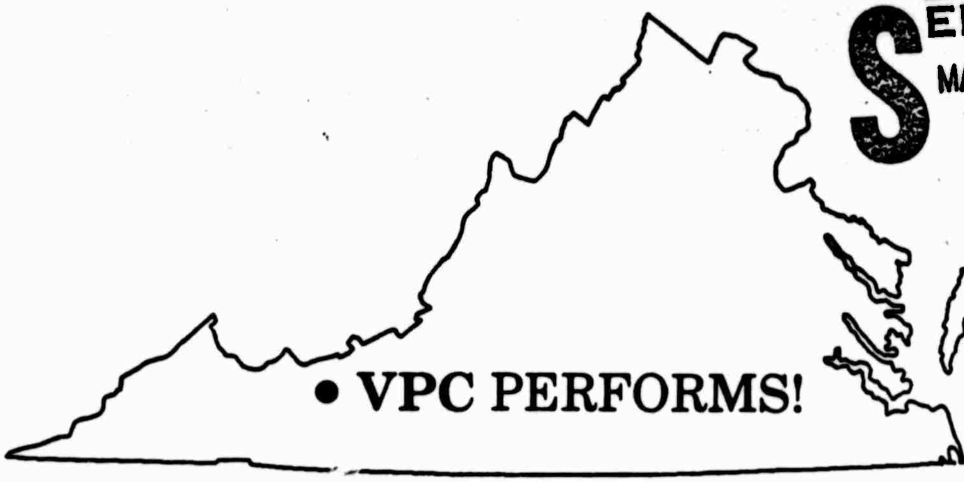
Productivity Measurement

and Incentive Methodology

(Phase III - Paper Test)

Volume I








Virginia Polytechnic Institute
and State University

Blacksburg, Virginia 24061

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The Study of

Productivity Measurement

and Incentive Methodology

(Phase III - Paper Test)

Volume I

FINAL REPORT

March, 1986

Defense Supply Service - Washington

Contract MDA 903-85-C-0237



VIRGINIA PRODUCTIVITY CENTER

VPI & STATE UNIVERSITY

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THE OVERALL GOAL OF THE FIVE-PHASE STUDY WAS TO IDENTIFY AND DEVELOP PRODUCTIVITY MEASUREMENT AND METHODOLOGIES AND MODELS THAT WILL EFFECTIVELY INTEGRATE WITH GOVERNMENT TO CONTRACTOR INCENTIVE METHODOLOGIES. THE PHASE III REPORT CONSISTS OF THREE VOLUMES. VOLUME I CONSISTS OF A DETAILED SUMMARY OF THE PHASE III STUDY; VOLUME II, A DETAILED ANALYSIS OF THE MODELS TESTED; VOLUME III, FINAL REPORT BRIEFING AT DSMC.

IN PHASE III, THREE PRODUCTIVITY MEASUREMENT/EVALUATION MODELS WERE "PAPER" TESTED AGAINST A GENERIC SET OF CRITERIA TO DEPICT THE RELATIVE STRENGTHS AND WEAKNESSES OF EACH MODEL AS DIRECTLY RELATED TO THE INTENDED APPLICATION.

THE PAPER TEST REVEALED THE CRITICAL NEED TO DEVELOP A PRODUCTIVITY MEASUREMENT METHODOLOGY FOR DEFENSE CONTRACTORS THAT REPRESENTS A GRAND STRATEGY WHICH CAN BE TAILORED TO SUIT SPECIFIC SITUATIONS AND CIRCUMSTANCES.


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# THE STUDY OF PRODUCTIVITY MEASUREMENT AND INCENTIVE METHODOLOGY (Phase III - Paper Test)



FINAL REPORT

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Defense Supply Service - Washington

Contract No. N00039-84-C-0346
VPI and State University

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# I. EXECUTIVE SUMMARY

## Purpose of Study

The overall goal of this study (Phases I-V) is to identify and develop "productivity" measurement and evaluation methodologies and models that will effectively integrate with government to contractor incentive methodologies. The government (client/customer) undertandably wants/needs to improve the performance of defense-related systems (i.e. reduce costs, increase quality, improve responsiveness, improve design to production to delivery transitions, etc.) for acquisition purposes. The contracting firm understandably wants/needs to improve its performance (i.e. increase profits, reduce costs, increase quality, improve productivity, improve efficiency, spark innovation, etc.) so that it will be competitive, grow and survive in both the short- and long-term. Government to contractor incentive/(gain sharing) methodologies such as IMIP are viewed as a way to create win-win situations for both the government and defense contractors, thereby satisfying the goals of each. The primary benefits of such improved performance systems are reduced costs, while maintaining or improving the quality of these systems. Examples of secondary benefits are: increased production capacity due to expanded or modernized facilities, shared savings to offset lost profits to the contractor, technological innovation that may have otherwise been prohibitively expensive, proactive producticity management efforts, etc. There are fairly obvious company specific benefits as well as defense contractor system-wide benefits.

A program of the scope and character of incentive methodologies such as IMIP is obviously complex. There are many elements of an overall program that must work together successfully in order for the intended desired outcomes to be achieved. Critical elements involved are those of measurement and evaluation. Why? First, it is implicitly clear that one cannot manage what cannot be measured. Secondly, it is clear that the government (client/customer) cannot share benefits unless these benefits can be verified. We must be able to validate that productivity improvement interventions (manufacturing improvements) have the positive impact they were projected (cost-benefit analysis) to have. Thirdly, measurement and evaluation systems should be designed so as to motivate, promote, and encourage proactive productivity improvements. We need to measure in order to provide positive feedback to the system. We need improvement-encouraging measurement systems to ensure that productivity improvement is an integral, and continual, part of the contractor's management process. This ensures that improvement efforts go beyond the major, project-oriented, manufacturing investment projects currently supported by Industrial Modernization Incentives type programs. Fourthly, we need to measure and evaluate so that we can control improvement implementation, and ensure effective and efficient execution of productivity improvement interventions.

The purpose of the Phase III part of the overall study (Phases I-V) was to investigate selected productivity measurement/evaluation models. Further, the purpose of the Phase III study was to evaluate these models (or methodologies as the case may be) in terms of their ability to satisfy the four basic goals of measurement listed above. Three models and one methodology were investigated by a "paper test." The three 'models' were: (1) the Multi-Factor Productivity Measurement Model (MFPMM), (2) Price Waterhouse's Automated Cost Baseline Generator (ACBG), which is the software tool that accompanies their Cost Definition Methodology (CDEF), and the Discounted Cash Flow/Shared Savings Model (DCF/SSA). The one methodology investigated was the Ling-Temco-Vought, Vought Aerospace Products Division, integrated productivity measurement system (LTV/VAPD). The distinction between the terms, model and methodology, are clarified in Section III of this Final Report.

Report Contents

The Final Report consists of three volumes: Volumes I, II, III. Volume I is a detailed summary of the Phase III Study, Volume II presents a detailed analysis of the models tested (i.e., the results of the "paper tests"), and Volume III consists of the Final Report briefing materials presented to DoD on January 17, 1986, at the Defense Systems Management College in Ft. Belvoir, VA. The total Final Report is divided into eight sections with selected appendix material (Volume I -Sections I-VI; Volume II -Section VII; Volume III -Section VIII). This current section, the **Executive Summary,** is intended to provide guidance as to how the Final Report can best be used, and to summarize the basic findings. **Section II** provides the reader with background material as to the goals and objectives of the overall study (Phases I-V) and the results of earlier completed Phases (I&II). **Section III** provides the reader with a little more detail on Phase III and the results of the six-month study. **Section IV** provides a field site description for LTV/Vought Aero Products Division and for a typical aerospace and defense contractor. The intent of this section of the report is to acquaint the reader with the field site for the study (i.e. where the paper test of the three models were completed). The section also provides a description of a "typical" defense contractor so that the reader may compare and contrast LTV/VAPD with that description. This comparison is important if the study results are to be broadly interpreted and applied. **Section V** presents the general approach taken in the Phase III study and the results achieved. The section is lengthy and quite detailed, with the general approach taken being described in subsection V.A. and each model described in some detail in subsection V.B.1-4. Applications of each model are discussed in subsections V.C.1-3. Also, criteria used to evaluate each model from the perspectives of productivity measurement and an incentive methodology are presented in Subsection V.D. Each model is evaluated against these criteria in subsection V.E., and then the LTV/VAPD integrated methodology is also evaluated in Subsection V.F. Section V of the Final Report is a very important section and should be studied carefully by the serious reader/evaluator.

**Section VI** provides specific recommendations and conclusions that are based upon the Phase III study. Recommendations relative to Phases IV & V are also included in this section. **Appendix A** includes a detailed description of each model/methodology investigated. **Appendix B** contains a Bibliography (updated from the Phase II Final Report - 1983).

**Section VII** (Voume II) provides a very detailed analysis of each model. It represents the paper test itself and responds to all the specific questions raised in the RFP and identified in the objective set (i.e., objectives 2 and 4). **Section VIII (Volume III)** includes copies of all the materials used by members of the research team to present a Final Report Draft briefing to DoD representatives on January 17, 1986, at the Defense Systems Management College in Ft. Belvoir, Virginia, and also a briefing presented to the Deputy Assistant, Secretary of Defense, on February 18, 1986, at the Pentagon.

Major Assumptions/Study Constraints

This project began with a broadly stated scope of objectives. Due to budget constraints and the number of models to be tested, the scope of the study was delimited significantly from the original intent of the RFP to the finally accepted proposal. Therefore, we feel it is important to state implicit assumptions and study constraints. The intent is to recognize the limitations upon our ability to extrapolate findings from this study to the entire defense contractor environment. We do not wish to mislead readers as to the extent to which these findings are widely applicable in all contractor settings and applications. We only utilized one field test site, although the research team has broad and extensive experience with other defense contractors. Our data, therefore, comes primarily from one site, while our experience is much broader.

We assume that the LTV/VAPD is a fairly representative defense contractor. However, we recognize that there are many dimensions over which contractors will vary (i.e., commercial vs. government business mix, prime contractor vs. subcontractor, management style, technology employed, line of business, size, etc.). We have attempted to describe the field test site as well as possible in Section IV-A. We also attempt to describe a "typical" aerospace and defense contractor/subcontractor in Section IV-B. The intent is to allow the reader to conclude whether conclusions drawn from our field test site are transferable to other sites.

We are confident that the models themselves can and do work in this environment. They each perform the tasks they were designed to accomplish. What we are unsure of, due to the limited scope of testing done due to study budget constraints, is the extent to which these models will be endorsed by the contractor community and can be developed into a management system (i.e., a productivity management methodology).

We <u>do not</u> assume that these three models represent the universe of models available to accomplish the desired objectives of the government. They certainly do not represent necessary or sufficient tools that a government contractor must use to succeed in business. They do, however, represent three state-of-the-art approaches to measurement and evaluation of performance in this environment. LTV has shown that, when combined into an integrated system, they represent a sophisticated and useful management system.

Major Findings

1. None of the three models tested will accomplish all of the objectives desired by the government or by contractors.
2. A methodology which incorporates the use of a variety of measurement and evaluation models, such as the MFPMM, CDEF, and discounted cash flow models, is required if all the desired objectives of both the government and contractors are to be satisfied.
3. Each of the three models tested has "soft spots" or current developmental problems that need to be, and are being, worked on. All of these models are relatively new developments that do have excellent potential.
4. Variances in operating systems, management styles, pressures and priorities, perceived problems and opportunites, and skilled/competent productivity management personnel will very likely make it very difficult to translate and transfer models and methodologies from one company to the next. The issue/problem of translation and effective transfer needs to be thought through very carefully.
5. Each of the models that were paper tested was initially designed to accomplish objectives that the project team recognizes as subsets of a total productivity managment program. The challenge,

then, will be to identify the areas relating to a total productivity management program where the models overlap and the areas which the models do not address.

The Final Report presents a preliminary perspective on how these models can be combined into an effective productivity management methodology. This effort will be enhanced through a case example of a defense contractor that has developed an integrated productivity methodology.

6. Of the three models tested, only the MFPMM actually measures total input-output productivity. The DCF/SSA model is an analysis tool designed to help management and the government evaluate the merits of selected productivity improvement interventions. It is best described as an analysis and decision-making tool for planning and forecasting purposes.

   Price Waterhouse's Cost Definition Methodology is an approach developed to prepare performance and cost baseline data in support of commercial factory modernization or Department of Defense IMIP's. CDEF utilizes a top-down analysis technique which facilitates the identification of appropriate performance and cost measurement criteria, selection of improvement opportunites, and economic justification of identified investments. CDEF (particularly the cost-benefit tracking portion) evaluates project productivity strictly from the expense perspective, and does not include an analysis of the revenues generated by the project. Each of the three models was designed to accomplish an important part of the overall goal that DoD and contractors have established in IMIP-type programs.

These three models, when viewed together, constitute a potentially satisfactory methodology which can accomplish what the government and contractors want to do. Independent of other models and systems, each model is not sufficient to accomplish the overall goals desired by the government and defense contractors.

7. There are deficiencies in the software developed by the Logistics Management Institute to implement the DCF/SSA model. These are identified by LTV in subsection VII-D-2 of the Final Report. Westinghouse also found deficiencies in this model and have developed their own version of the DCF/SSA model. From the perspective of LTV, the Westinghouse version also has some shortcomings (see subsection VII-D-3). As a result, LTV is in the process of designing their own version of the DCF/SSA model.

8. The MFPMM must be modified rather significantly to function in the defense contractor environment. LTV has successfully made this conversion and have found

the model useful as an integral component of their productivity management methodology. There are some developmental issues associated with the model that still need to be resolved.

9. The Price Waterhouse model performs well against the criteria for which it was designed. The up-down activity structure required for data analysis may differ from a company's organizational structure; therefore, a node-tree structure must be developed. The effort required to execute this step will depend upon the complexity of the processes or activities performed by the company.

The Price Waterhouse model is being implemented on numerous IMIP and ManTech projects, with ACBG being used on several of these efforts. Due to the complexity of the LTV operations, LTV perceives the cost to implement the complete CDEF methodology to be high relative to their current method of performing cost-benefit analysis and tracking. Section VII-F contains a response from Price Waterhouse to many of the issues raised by LTV.

10. It is believed that each model tested will work in the defense contractor environment. They each were designed to accomplish specific objectives and are useful for those purposes. In order to develop a comprehensive productivity management effort; however, a combination of performance

measurement and evaluation techniques are required. The analogy of a crown of jewels might be used to illustrate the relationship. The models tested represent the jewels and are valuable in their own right. However, when the jewels are placed in the crown (models built into an integrated methodology), they take on added value.

Recommendations

We believe there is a need for a more systematic and disciplined productivity management effort in the defense industry. Improved measurement and evaluation systems must play a key role in this effort. Measurement and evaluation is complex in this industry and no single model will suffice. Each of the three models tested in this study can, and have, played a significant role in productivity management efforts within the industry. We believe further development of the three models is therefore necessary. Perhaps more importantly, a generic methodology for productivity management efforts within the industry needs to be further developed and communicated. The role that these three models, and others, play in that methodology needs to be understood by a broader audience within the industry if any real impact is to be made.

There is a reasonable consensus among the research team as to how to proceed during Phases IV and V of the overall study. It has been agreed that proceeding with a field test for the CDEF model, as outlined in the original proposal, is not economically feasible without significantly reducing the scope of the application. Since LTV is developing their own version of the DCF/SSA model, field testing that model, per se, does not make sense. The MFPMM would stand to benefit most from a field test as outlined in the proposal.

The general recommendation regarding a continuation of the research is to combine Phases IV & V into a single, 18 month project which would develop and test a comprehensive productivity management implementation guide. The effort would focus on resolving specific developmental needs of the three models via a modified, scaled-down field test at LTV/VAPD. We would additionally, "field test" the methodology, and the models, with representative defense contractors in an intensive workshop setting. A detailed analysis of responses from sampled contractors would be made to assess points of resistance and implementation barriers. A draft implementation guide would be reviewed during these workshops to ascertain the level of industry resistance/acceptance. A final implementation guide would benefit from expanded exposure to other contractors beyond LTV/VAPD and our industrial advisors. The models and methodology would benefit from continued detailed analysis and development with LTV/VAPD to the extent necessary.

## Conclusions

The paper tests of the three models have provided valuable information for developmental purposes. The details of the paper tests in Section VII identify specific developmental needs and describe how the models apply (or might apply) in a defense contractor setting. With respect to serving as a productivity measurement/evaluation/support tool for incentive methodology, each model has strengths and weaknesses. Such ambivalence is simply due, first of all, to the fact that a productivity "model" is only a component of a productivity program or methodology. It is believed that only a broad-scope productivity program can satisfy the joint goals of the DoD and defense contractors as specified by IMIP requirements. Thus, to expect a single model to satisfy these joint goals and to meet all the specifications for an incentive methodology is probably unrealistic.

An attempt has been made in this Final Report to evaluate each of the three models against a generic set of criteria in order to depict the relative strengths and weaknesses of each model as directly related to the intended application (see Subsections V.D. and V.E.). The reader is cautioned against viewing the term weakness as a weakness of the model itself. Rather, the issue of weakness for a particular model relates to the model's performance against a criterion established for an application for which the model may not have been initially designed.

The paper test has revealed the critical need to develop a productivity management methodology for defense contractors that represents a "Grand Strategy," which can then be tailored to suit specific situations and circumstances. Within this "Grand Strategy," there will be planning, measurement, evaluation, control, and improvement needs. Defense contractors and the DoD need to have a clearer understanding of how these three models fit into an overall productivity management methodology. The research team offers an initial version of the Grand Strategy in Section III. However, much more development should be done in Phases IV and V of the overall study.

A bottom-line conclusion is the belief that the goals these three models were designed to meet, and information they were designed to provide, are essential to executing an effective incentive methodology in the defense industry. The paper tests have succeeded in collecting the information they were supposed to collect. Assuming LTV/VAPD is a typical aerospace contractor, more is now known about how these models can and will work in the defense industry. The key questions to be answered next relate to translation in the form of an Implementation Guide and the transfer of this information to the general defense industry community. Subsequent development and refinement of the models should proceed simultaneously with the design of a process to address the translation and transfer questions.

# II. BACKGROUND

## A. Overall Project Goals (All Five Phases)

Productivity in the defense industry can be and needs to be improved. Additionally, the deteriorated condition of the defense industrial base has prompted increased concern over its capability to respond to mobilization requirements.

Initiative Number 5 of the Acquisition Improvement Program was directed at encouraging capital investment to enhance productivity. In addition to contract financing improvements, several productivity actions have emanated from the spirit of the Acquisition Improvement Program. A newly established Industrial Productivity Directorate within OSD has the responsibility of providing leadership in the productivity area. They serve as a focal point, facilitator, and advocate on productivity issues. Also, a DoD Industrial Modernization Incentives Program (IMIP) was initiated which targets industry through incentives to substantially increase its capital investments with its own financing in modern technology, plant and equipment for defense work.

A requisite for productivity rewards (sharing) is the ability to accurately measure and track a contractor's productivity gains. At present, contractor efficiency and productivity cannot be readily measured and related to a contract. A practical method of measuring productivity and effecting rewards must be developed to stimulate improved productivity.

(Taken from final report entitled Contractor Productivity Measurement, APRO 83-01, Final Report, APRO, Fort Lee, VA 23801)

1. Study Scope

Phases I and II of the overall study investigated ways of measuring contractor productivity and relationships between possible measurement techniques and associated potential productivity incentives. Alternatives for measuring productivity, the type of productivity data needed, the type of data currently available, and the degree to which the data would be verifiable and suitable as a basis for appropriate contract incentives were explored. The study also looked at proposed incentives from the standpoint of productivity related information needed to support the incentives.

2. Study Objective

The objective of this study was to develop and test measurement systems which (1) are designed to complement IMIP by providing a productivity measurement and tracking system and, (2) may provide a basis for contract incentives to motivate contractors to improve their productivity through methods changes, management improvements and other means in addition to capital investment. Specific subobjectives proposed to accomplish this were:

Phase I. Develop specific definitions of contractor productivity appropriate for the products concerned and the contracts involved.

Phase II. Design measurement techniques that allow for establishing a baseline, tracking performance, and showing auditable results. Synthesize the definitions, measurement techniques and reward mechanisms.

Phase III. Relate these measurement techniques to incentives and reward mechanisms.

Phase III & IV. Test the proposed methodology on representative contracts and contractors to determine the suitability for DoD implementation.

Phase V. Based upon the test results, recommend DoD policy and procedure coverage, as appropriate.

3. Study Approach

A study that addresses defense contractor productivity measurement is a high-risk effort in terms of probability of success, but it has tremendous potential benefits to be shared by all. To reduce the risks and improve the probability of success, top-level management within DoD and each of the military services has supported this effort. To improve the chances for system acceptance and to establish credibility throughout the defense community, DoD and the defense contractors have been involved in system development.

The study team for this DoD effort supporting IMIP included representatives from the following organizations: Defense Systems Management College (DSMC), Army Procurement Research Office (APRO), Naval Office for Acquisition Research (NOAR) and Air Force Business Research Management Center (AFBRMC). The representatives shared the responsibility for completing the following actions to meet the study objectives:

(a) Review pertinent literature and current policy relating productivity.

(b) Design a contractor survey and distribute it to defense contractors through an industry association.

(c) Analyze literature and survey responses.

(d) Contact Government personnel in those functional areas impacting productivity measurement for insights into relationships.

(e) Visit selected contractors responding to the survey for detailed follow-up discussions.

(f) Synthesize proposed productivity measurement methodology based upon analysis and findings.

(g) Design test plan.

(h) Conduct test.

(i) If warranted, develop implementation guide.

Actions (b)-(e) constituted Phase I of this five-phase project. This phase was directed and coordinated by APRO. Action (a) and (f) constituted Phase II of the project entitled The Development of a Taxonomy of Productivity Measurement Theories and Techniques. This phase was executed by Dr. Scott Sink (P.I.), then at Oklahoma State University as Director of the Oklahoma Productivity Center, and Dr. Thomas Tuttle, Director of the Maryland Center for Productivity and Quality of Working Life. (Sink, Tuttle, DeVries, and Swaim, 1983).

Action (g) constitutes Phase III of this project and is the focus of this final report. Action (h) constitutes Phase IV and Action (i), Phase V. Phases IV and V are optional and contingent upon the results from Phase III and funding availability.

B. Phases I and II Results

We will not attempt to replicate what was reported in the 1984 (June) APRO Final Report or in the 1983 (November) Oklahoma State University/Oklahoma Productivity Center (OSU/OPC) Final Report. However, it may be beneficial for the reader to see a summary of the results from the first two phases of this project.

1. Phase I Results

The need to improve productivity within the defense industry is clear. Escalating weapon systems production costs, a deteriorating defense industrial base, and foreign competition provide the unmistakable evidence. DoD's Industrial Modernization Incentives Program (IMIP) was initiated to address this need by incentivizing defense contractors to improve productivity. This research complements the IMIP effort.

(a) Productivity Measurement Practices.

Research conducted to date has identified current contractor productivity measurement practices. Contractors responding to a survey of measurement practices ranked profitability most important on a list of organizational performance evaluation factors. If used at all, productivity was usually ranked fifth, after profitability, effectiveness, quality and efficiency.

Problems encountered by the contractors measuring their productivity were usually due to the complexities of quantifying and relating the various input and output factors involved. Also, meaningful indices were not readily available to identify productivity impacts on functions other than production.

The respondents indicated a desire to keep any proposed productivity measurement system simple and to base the reward for productivity gains on the cost difference between a baseline and achieved cost, adjusted for inflation. This is basically the way DoD currently attempts productivity measurement and its associated profit reward in the weighted guidelines methodology, but it has not been successfully implemented as currently structured.

There was no evidence of a total factor productivity measurement system implemented by the survey respondents, although some attempts were being made to develop such. Multiple indices were often used; however, they were not integrated as required in a total factor approach. The most popular productivity or performance-related indices being tracked by defense contractors were value added/employee and a comparison of standard hours to actual hours for work performed. Some confusion existed as to whether an index was a productivity measurement (i.e., output/input) or some other performance measurement.

Production cost visibility varied widely among the contractors visited, but all could provide direct labor and material costs through work center tracking. Unfortunately, direct costs constitute a small and decreasing percentage of total cost, and therefore are becoming less useful as the sole basis for productivity measurement. Indirect costs are substantial and must also be addressed.

Tracking the impact of an investment for productivity improvement in the indirect areas gets obscure, and these areas frequently increase with a decrease in direct costs. The multiple product, plant and customer environment found at most contractors visited further inhibits accurate cost tracking of the impact of investments in productivity enhancing equipment. Also, the follow-up verification of productivity gains was somewhat lax, especially in the indirect areas.

From the discussions with the contractors visited, it appeared that investments were mostly for competitive and technological reasons rather than simply for cost reduction on the current contract. Contractors tended to plan ahead to other contracts and products and make investments accordingly to improve their long run situation.

2. Phase II Results

This research also identified a number of available tools to measure productivity and to help bring about required improvements. The report identified, explained, classified, and evaluated existing productivity measurement practices, theories and techniques. These techniques included both productivity and surrogate measurement systems. Surrogate, or substitute, measures are those which measure variables that are related to productivity (e.g., scrap reduction, cost reduction), but do not measure productivity (output/input) directly. Productivity improvement efforts and accomplishments can be, and are being, measured without the aid of productivity measurement and evaluation techniques.

While any of the measurement tools identified can be, and should be, used by defense contractors to measure and improve their productivity, only three have the potential to directly complement IMIP. These are the Multi-Factor Productivity Measurement Model (MFPMM) and two surrogate techniques - the Cost Benefit Analysis/Cost Benefit Tracking (CBA/T) methodology and the shared savings techniques. Only the MFPMM and CBA/T can provide a basis for determining savings (productivity gains). The output (savings) is used to drive the DCF Model that calculates the shared savings needed to achieve an acceptable rate of return. However, net savings that can be passed on to the customer (e.g., Dept. of Defense) through price reductions needs to be in compliance with the estimating methodology (i.e., rates and factors) defined in the contractor's disclosure statement.

Productivity measurement technology is currently able to provide accurate productivity data to business managers. Although the technology does exist, there are several reasons why industry, in general, is not taking full advantage of state of the art techniques.

(a) Knowledge of the existence of specific productivity measurement techniques is generally not widespread. The body of industrial engineers, productivity managers, and other individuals interested in productivity measurement is growing; however, discussion of productivity methodologies outside this relatively small group is rather limited to the general category of input and output.

(b) The state-of-the-art techniques are less complex than they appear, yet they do require substantial effort to actually implement. Management information systems are required to generate, organize, and interpret data and track productivity improvements. Many smaller organizations might consider gross indicators of cost and output as an acceptable alternative to establishing an entirely new area of effort and personnel devoted to researching and implementing a complex productivity measurement system.

(c) Some of the macro-measurement and other surrogate techniques may be adequate for individual manager's needs. Small job-shop operations, speciality business, and other low volume or less complex organizations do not require the elaborate measurement techniques that a large, complex, multi-product, high-volume organization requires to remain competitive.

The above comments are as appropriate for a defense contractor as they are for industry in general. Results of the industry survey indicate that productivity factors were ranked low relative to other measures of organizational performance. The defense contractors' inattention to productivity measurement is understandable for two reasons.

(1) Defense contractors are generally not motivated to improve productivity because productivity improvements reduce cost and defense contractor profit opportunity is cost based. As long as this negative incentive exists, contractors cannot be expected to voluntarily initiate a unilateral program to improve

productivity. As one attendee remarked at the 1984 Aerospace Division Conference of IIE, the government's profit policy has "incentivized contractors into stagnation."

(2) State-of-the-art productivity measurement methodologies require data analysis. Existing management information systems may not be sufficient to provide the data required in terms of type, degree, or format. One example is the indirect cost contribution of a new item of capital equipment to one of many products or other cost objectives. Without specific government direction and corresponding consideration, it is not reasonable to expect defense contractors to initiate changes to accounting systems and information systems in order to implement a productivity measurement system. This is especially the case if the end result is a reduction of their cost base for profit opportunity.

The DoD is committed to improving the productivity of industrial firms which develop, build, and maintain weapon systems, sub-systems, and spare parts for the armed forces. Manufacturing Technology (MANTECH), Technology Modernization (TECHMOD), multi-year contracting, and accelerated depreciation are only a few of the programs which have been instituted by DoD to motivate subcontractors to achieve higher productivity. The Government is also sharing the cost of new equipment and processes and cost savings with Contractors. The primary element lacking in the program is a productivity measurement methodology for assessing a contractor's productivity over time and, in some instances, between firms or the various plants or profit centers within a firm. This methodology should be valid, simple, consistent, reliable, and obtain data from existing systems or sources (Section C.3.0, Background, Statement of Work for Taxonomy of Productivity Measurement Theories, RFP F33615-83-R-5071).

Investigations of productivity measurement theories and techniques in the literature (and in practice), and investigation of IMIP, MANTECH, and TECHMOD policies and procedures lead to the belief that there is a fundamental confusion between the concepts of "productivity measurement," and "productivity improvement measurement, evaluation, and verification." The mission of the Phase II study was to present, describe, analyze and assess existing productivity measurement theories and techniques. The techniques presented in the Phase II Final Report (MFPMM, MCP/PMT, NPMM, and Surrogate measures) are, in practice, customized to suit the needs/characteristics of the organizations implementing them. Still, the application of each productivity measurement/ evaluation technique (however customized) can fundamentally cause and/or facilitate productivity improvement and control.

Productivity improvement efforts and accomplishments, regardless of their source can, and should be, measured and evaluated. However, productivity improvement efforts and accomplishments can be measured and evaluated without the aid of formal productivity measurement and evaluation techniques.

This distinction is at the heart of the relationship between the Phase II study and IMIP. Specific productivity improvement and cost reduction measurement, evaluation and verification procedures can be, and are being developed. They utilize cost accounting systems, work standards data, engineering economic analysis, and conventional contracting procedures. Further, these procedures can be customized specifically to track projected and actual savings. If adequate incentives on both sides of the contact process exist then we can assume that each side, Government and contractor/sub-contractor, will work diligently to develop valid, effective, and efficient measurement, evaluation and justification systems and procedures.

At the conclusion of the Phase II study, it was not clear how the existing productivity measurement and evaluation techniques could, would or should interface with needed productivity improvement and cost reduction measurement, evaluation, and justification procedures. This was, in the opinion of the researchers, the next logical step to take in the development of IMIP measurement, evaluation, and justification procedures.

3. Implications for IMIP

In addition to identifying the above techniques, a number of insights were gained that impact application of productivity measurement systems in IMIP. First, it is important that any system address indirect as well as direct costs. Indirect costs, such as for "information workers," constitute a large and increasing percentage of total contract cost and must be assessed directly rather than through burdening mechanisms on direct costs.

Current cost and financial accounting systems are not directly providing the cost visibility required for productivity control. It is important that productivity be related to profit and manufacturing managers use productivity information feedback to manage and to direct changes and improvements. It may be that either minor restructuring of expense accounts or simply tracking and extracting pertinent cost factors through the more sophisticated cost accounting systems will provide the desired visibility. The manufacturing costs are the same - they are just sliced differently to reflect specifically where costs occur and to show how they change.

The degree of change required to provide the cost visibility depends on the existing accounting system and desired visibility. The MFPMM, which is already accounting system based, can provide the desired visibility depending upon the input and output factors selected for tracking. While the CBA/T methodology presents a new accounting perspective, it is not necessarily compatible with classical accounting. If radical restructuring is not possible or desired, templates or links could be established to extract the cost information from existing systems into a format more suitable for productivity and manufacturing cost analysis.

DoD's focus on contractor productivity is best made at the macro level of profitability and productivity as it relates to specific contracts. The micro look at cause and effect of productivity changes from period to period should be left to the contractor. This does not mean the productivity measurement system must attempt to address all factors of production. This may become too complex and costly to maintain. Rather, an attempt should be made to minimize the cost of the measurement and tracking while considering the benefits received. The system should, though, be detailed enough to accurately identify areas for productivity changes.

Although the defense industry in general is not currently motivated to take advantage of state of the art productivity measurement techniques, contractors operating under (or considering involvement with) IMIP procedures are highly motivated. The IMIP provides for sharing of cost savings due to productivity improvements. Measurement and tracking are crucial to credible development of the amount of savings to be shared. Since profit in this case is not cost based in the traditional manner, contractors are not negatively incentivized. Additionally, the implementation of a productivity measurement system or methodology in itself should be considered a productivity improvement. The cost to implement a system (investments) could/should be treated as an initial offset from calculated savings prior to sharing, and the maintenance of the system could/should be treated as an indirect expense, and included in the rates and factors used. As a minimum, the implementation should be negotiable for on-going programs and considered in the business arrangement for new entrants to IMIP.

Since techniques are available to measure productivity improvements, the issue of concern to IMIP is which technique or combination of techniques will provide data to satisfy both the government and industry?

4. Recommendations from Phases I & II

(a) DoD should test the following selected techniques in a defense contractor environment:

(1) Multi-Factor Productivity Measurement Model

(2) Cost-Benefit Analysis/Tracking Methodology

(3) Discounted Cash Flow Model

The tests should be conducted at multiple sites with a paper test preceding a live test. The tests will serve to verify the applicability of each technique to the defense industry and to identify areas needing correction or enhancement before widespread implementation. The tests should also allow for a variety of comparisons among the different techniques in such areas as accuracy, consistency, efficiency, and sufficiency.

(b) Recognizing that no single productivity measurement system will meet every DoD and contractor management need for productivity information, it is recommended that criteria be established which a contractor's system must satisfy rather than dictating a universal system that all must adopt. This concept is similar to that used for the Cost/Schedule Control System Criteria (C/SCSC) and allows the contractor considerable flexibility. The criteria will provide the basis for determining whether a contractor's productivity measurement system is acceptable. It will set forth characteristics which a contractor's system must possess and specify the type of information which can be derived from the system. It may be possible that the productivity measurement system criteria could be integrated into a broader information reporting system such as C/SCSC.

(c) This research has identified a number of productivity related areas that need further development. Two of particular importance are (1) capacity utilization and how it relates to productivity and (2) productivity measures for indirect labor (i.e., information/knowledge workers). Productivity and efficiency measures for indirect labor are becoming increasingly pertinent, yet they are not nearly as well defined as for direct labor.

C. Phase III Goals

G(Phase III): to execute a "paper test" of the three basic models that takes generic and/or very specific descriptions of the models and evaluates model applications at a selected field site.

Objectives are:

$O_1$--Evaluate the ease of measuring and evaluating "productivity" using the three models in "paper-test" fashion.

$O_2$--Develop a comprehensive description of inputs and outputs for each model as applied in "paper-test" fashion.

$O_3$--Attempt to compare results of paper test from the three models.

$O_4$--Identify and describe in detail the data required to "drive" each model. Compare and contrast data requirements for each model.

$O_5$--Describe the level (unit of analysis) for which productivity was measured and evaluated in the field paper tests. Describe the most appropriate unit of analysis(es) for each model.

$O_6$--Evaluate the abilities of the models, in paper test application, to satisfy the overall project goal.

$O_7$--Describe incentive/reward system(s), if any, used by the field test site participating in this evaluation.

$O_8$--Recommend (not develop) modifications, if any, to any or all of the three models that would make them:

(a) easier to use

(b) easier to control

(c) easier to administer

(d) easier to obtain information

(e) easier to use incentives/reward applications.

$O_9$--Recommend whether to conduct a field test (i.e. Phase IV). Justify recommendation. Identify the company(ies) that will participate and provide evidence of their willingness to do so.

Project Management Objectives are:

$O_{10}$--Develop a detailed plan for Phase III execution. Review plan with the DSMC (COR) and review team at DSMC, Ft. Belvoir, Va. one week after contractor award. Agree upon plan.

$O_{11}$--Submit a written report summarizing decision reached at Initial Phase III planning meeting within two weeks after that meeting.

$O_{12}$--Submit monthly Progress Reports. (Note that we have altered the frequency of these progress reports to better fit project milestones, see project timetable for frequency and anticipated sequencing).

$O_{13}$--Make monthly progress briefings, which follow, by approximately 2 weeks, the written progress reports. (Note same change in frequency as for $O_{12}$.)

$O_{14}$--Execute paper test. We will not detail the specific activities here as they will be developed during the initial planning session. We have, however, indicated estimated travel and meeting times for on-site work by investigators.

$O_{15}$--Provide a draft report summarizing the paper test 18 weeks after contract approval.

$O_{16}$--Review comments and revisions for draft report. Pre-pare and submit final report on or before the 26th week after contract approval.

D. Phases IV & V Goals

Phase IV goal is to execute a field test of the three models to further evaluate and develop model applications. Objectives for Phase IV are:

$O_1$--Develop a field test plan acceptable to the COR.

$O_2$--Measure productivity (or evaluate cost changes) over a period of time at the various field test site using these models. (One field test was requested by DSMC at budget negotiation phase).

$O_3$--Ensure that sufficient test data points are included in the measurement tests to ensure as much validity in conclusions and inferences to be drawn as possible.

$O_4$ -- Field test all three models (MFPMM, CBT/A, and IMIP (DCF/SSA)).

$O_5$ -- Prepare and submit a report on the results of each field test. Report must address the following:

(a) ease of measuring productivity and tracking costs in field test for each model.

(b) description of the inputs and outputs for field application of the models.

(c) compare and contrast, where appropriate, the results of field test with the three models.

(d) identify and describe data required for field applications of the models. Compare and contrast data requirements for the three models.

(e) identify and describe the level (unit of analysis) for which productivity was measured and evaluated in the field application tests. Describe the most appropriate unit of analysis(es) for each model.

(f) evaluate the abilities of each model, in field applications, to satisfy the overall project goal.

(g) describe the field site incentive/reward systems. Evaluate the effectiveness of the site incentive/reward systems.

$O_6$--Evaluate an integrated productivity measurement system utilizing all or elements of the three models tested as an alternative measurement and evaluation approach to support an incentive methodology such as IMIP.

$O_7$--Recommend approaches the Services should pursue relative to measuring productivity and offering incentives and rewards for productivity improvement.

Phase IV Project Management Objectives: (Same objectives as for Phase III with exception of deadlines for draft and final reports. See project timetable.)

Phase V goal is to prepare an implementation report/manual that guides others in execution of recommendations and alternative approaches identified in Phases III and IV. Objectives are:

$O_1$--Develop and submit an implementation report that covers the following topics:

(a) What does each technique measure? Is there a clear understanding of the measurement? Can productivity be measured continuously, or must it be measured at specific intervals?

(b) What data are needed for the measurements? Are the data collected by a specific data collection system? Is there a general data collection system available or are data collection systems unique to each company?

(c) Are there data elements common to the difference measurement models? If so, to what extent are they common?

(d) Are there known relationships between unit price and area of productivity improvement by technique? What are the attributes that can be measured?

(e) What knowledge/experience do we have about the interaction of elements within a measurement technique? Is it possible for some element to show negative relationships?

(f) At what level (product line, organizational unit) should productivity be measured? How is this scaled to incentives and rewards?

(g) What is the range of incentives and rewards? Are the only funds available for rewards those funds that result from productivity improvements?

(h) How can the range of rewards be scaled? How should rewards be related to a company's risk, i.e., should the company be awarded the same amount for reducing overhead as for a major capital investment when the unit price declines by the same amount?

(i) What is the time scale for making productivity improvements? Does it vary for different organizational initiatives? How should the value of such improvements be determined?

(j) Who validates productivity improvements? Should the company state the improvements, and a Government agent validate them, or should an automatic system that allows an improvement to be measured on a continuous or random basis by the Government be used? Should a committee be used to validate (mainly from a subjective mode) improvements?

(k) Should the Government develop a technique that will measure the ratio of input to output, or should the Government consider productivity as it relates to reducing life cycle cost? Currently, productivity models do not seem to include the more global concepts of relaibility improvements, maintainability or reduced life cycle costs.

(1) Other considerations that should be taken into account under the subject of incentives and rewards:

a. Sole Source

b. Leader-follower

c. Production 1st run

d. Production Nth run

e. Competition

f. Multi-year

g. Multi-agency

h. Multi-product

i. Multi-location

j. Commodity/industry

k. GOCO operations

l. GFE/CFE

m. Integration

n. Subcontractors

(Objectives $O_2$ and $O_3$ added by Principal Investigator)

$O_2$--Develop a description of an approach for developing a strategic plan for an overall, comprehensive productivity management effort. Incorporate methodology for development of a comprehensive 2-5 year plan for productivity measurement and incentive methodology for Defense contractors and subcontractors.

$O_3$ -- Develop a description of what a comprehensive, integrated productivity measurement and evaluation effort would look like that incorporated use of all three models tested in this project.

Phase V Project Management Objectives: (Same objectives as for Phases III and IV with exception of deadlines for draft and final reports. See project timetable.)

## III. INTRODUCTION: PHASE III RESULTS

### Results: Research Goals and Objectives Accomplished

The goal of the Phase III study was to execute a "paper test" of the three models that takes generic and/or very specific descriptions of the models and evaluates model applications at a selected field site. The objectives were:

$O_1$--Evaluate the ease of measuring and/or evaluating productivity using these three models in paper test fashion.

$O_2$--Develop a comprehensive description of inputs and outputs for each model as applied in paper test fashion.

$O_3$--Attempt to compare results of the paper test from the three models.

$O_4$--Identify and describe in detail the data required to "drive" each model in paper test application. Compare and contrast data requirements for each model.

$O_5$--Describe the level (unit of analysis) for which productivity was measured and evaluated in the field paper test. Describe the most appropriate unit of analysis(es) for each model.

$O_6$--Evaluate the abilities of the models, in paper test application, to satisfy the overall project goal.

$O_7$--Describe incentive/reward system(s), if any, used by the company (field test site) participating in this evaluation. (Note: the RFP seemed to infer that the company was to be evaluated. We do not agree. The measurement and evaluation methodologies were evaluated. Our field site would probably not have participated if they felt they were being evaluated.)

$O_8$--Recommend (not develop) modifications, if any, to any or all of the three models that would make them:

(a) easier to use

(b) easier to control

(c) easier to administer

(d) easier to obtain information

(e) easier to use in incentives/rewards applications.

$O_9$--Recommend whether or not to conduct a field test (i.e., Phase IV). Justify recommendation. Confirm that LTV, Vought Aerospace Products Division, will participate in the field test and provide evidence of their willingness to do so.

This goal has been accomplished and the results are presented, with considerable detail, in Section VII. There were nine sub-goals or objectives for Phase III (see Section II-C) and they have each been accomplished. Objectives 1, 8, and 9 are addressed in Sections VI & VII. Objectives 2 and 4 are detailed in Sections V and VII. Objective 5 is specifically addressed in Section V and Section VII, subsections A thru E.3. Objectives 3 and 6 are dealt with in Section V.-D., E., and F. Finally, Objective 7 is addressed in Section IV. There is a direct translation of goals and objectives, as spelled out in the RFP, to those identified in the proposal and finally, to those accomplished in the research and documented in this Final Report.

Productivity Management Methodology for the Defense Contractor Industry

During the course of the research, the study team wrestled with the distinction between the concept of a methodology versus a model. Perhaps the Price Waterhouse development (CDEF) is a very good example of this distinction. There is a CDEF methodology that is spelled out quite clearly in

Section V. It represents an approach, a process, designed to assist management in gaining the support of DoD Industrial Modernization Incentives programs. The CDEF methodology is designed to integrate with existing management practices, while simultaneously preparing necessary information required to successfully execute IMIP-type efforts. The CDEF methodology is comprised of a specific set of models and techniques (i.e., CBA, CBT, ACBG). One must first understand the methodology in order to completely benefit from application of the models.

The same analogy holds true at a slightly more macro level relative to this study. One must understand a productivity management methodology or how to develop such a methodology in order to fully benefit from an application of the three models which were paper tested in this study. It was not within the scope of the contract to develop such a methodology, however, the research team found the process of developing a very rough first-cut methodology to be beneficial. Figure III-1 depicts the team's conceptualization of a generic productivity management methodology relative to the defense industry.

Note in this depiction of a methodology that each of the three models tested in this study can be identified within the methodology in terms of where they are most relevant and applicable. For example, the MFPMM is used by LTV as a STAGE 1 management support system. The Discounted Cash Flow models, such as the LMI and Westinghouse versions, are primarily STAGE 5 focussed. The Cost Benefit Tracking elements of the CDEF and MFPMM models are STAGE 9 focussed. The CDEF <u>methodology</u> is designed to interface with many of the stages in a productivity management effort as shown in Firgure III-1. The methodology depicts the process of identifying, selecting, paying for, implementing, and tracking performance for specific productivity improvement interventions in relationship with corporate or division strategic planning. One should compare and contrast this productivity management methodology with the one presented in Sink, Productivity Management: Planning, Measurement and Evaluation, Control and Improvement, 1985, John Wiley and sons.

FIGURE III-1
Generic Productivity Management Methodology
as Related to Defense Industry

**Corporate Strategic Plan** — STAGE 1

- Disclosure Statement
- CDEF
- MFPMM (LTV)

↓

**Factory/Division/Project Analysis** — STAGE 2

Incentives

- Developmental Plans
- Challenge Budgets (LTV)
- Cost Driver Analysis (LTV)
- Top Down IDEF, Node Structure
  Macro

↓

**Identification of Projects MEP vs. MIP** — STAGE 3

- Nominal Group Technique (LTV)
- IDEF (CDEF)
- ROM Potential Savings/ROI

↓

**Selection of Projects** — STAGE 4

- Decision Analysis
- MCP/PMT (LTV)
- CBA

↓

Figure III-1 (cont.)
Generic Productivity Management Methodology
As Related to Defense Industry

**Sources of Funds** — STAGE 5

- Man Tech
- Budget
- IR&D
- IMIP
- Profit

Various Return Analysis/Decision Analysis
Techniques Depending Upon
Audience/Funding (i.e. LMI, CBA, Westinghouse, DCF)

↓

**Negotiations** — NO GO → Different Source of Funds (Lost Profit in Case of no go IMIP) — STAGE 6

↓ GO

**IMPLEMENTATION** — STAGE 7

↓

**Cost-Benefit Tracking** — STAGE 8

↓

**Shared Savings Approach Incentive** — STAGE 9

- Rates and Factors Issues
- Projects vs. Overall Improvement Issue
- Validation Issues
- CBT

↓

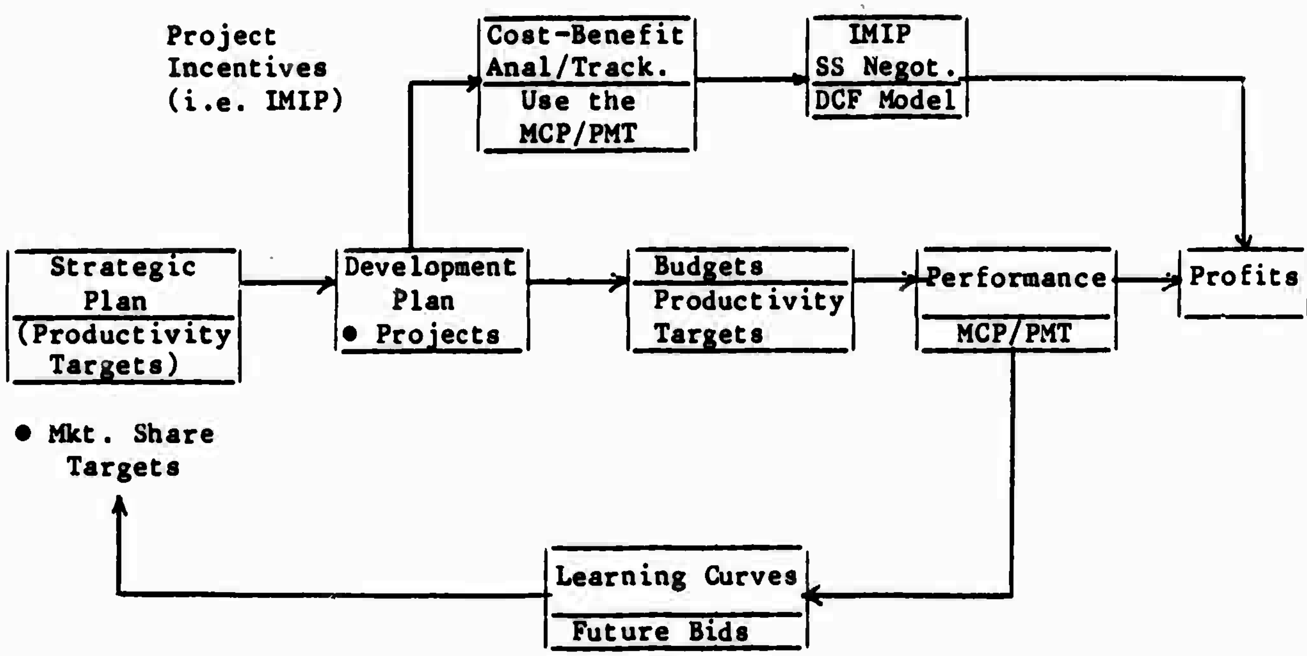
**Satisfaction of Government Objectives**

STAGE 10 (OUTCOMES)

- Improved Productivity
- Improved Competitiveness
- Improved Performance
- Reduced Costs; Improved Quality, Improved Overall Acquisition for Government

An example of how a specific defense industry contractor has taken this generic methodology and developed a disciplined application is depicted in Figure III-2.

FIGURE III-2
Depiction of LTV/VAPD's Basic Approach
to Productivity Management




Comments:
- Process should be self-motivated
- IMIP utilized to minimize lost profit impact
- If there were overall total productivity improvement incentives the company would likely do what Government is after anyway and with less difficulty than by way of project focussed incentives.

Key for Figures III-1 & 2

CDEF = Cost Definition Methodology
MFPMM = Multi-Factor Productivity Measurement Model
ROM = Rough Order of Magnitude
ROI = Return on Investment
MCP/PMT = Multi-Criteria Performance/ Productivity Measurement Technique
CBT = Cost/Benefit Tracking
CBA = Cost/Benefit Analysis
IDEF = An ICAM Definition Language (Modeling Techniques)
MEP = Modernization Efficiency Projects
MIP = Modernization Investment Projects
IR&D = Investment Research & Development
IMIP = Industrial Modernization Incentives Program
LMI = Logistics Management Institute
DCF = Discounted Cash Flow
SSA = Shared Savings Approach

In this figure, note that the same basic process, as portrayed in Figure III-1, is followed but the specific models used are different. The goals are the same, but the paths are slightly different based upon specific systems, management style, culture, and situations. It is doubtful that many defense contractors could explicate their productivity management methodology nor demonstrate consistent, disciplined, and systematic use of state-of-the-art productivity measurement models and techniques.

Results of the Phase III study suggest that models and techniques applied in the absence of a methodology, a strategic plan, or a "Grand Strategy" seldom accrue the potential benefits available from their application. Although that which follows are the results of paper tests on three specific models, the reader is cautioned to not lose sight of the forest for the trees. The "forest" is the Productivity Management Methodology and the "trees" are the individual models.

## IV. FIELD SITE DESCRIPTION

The three productivity-related models were "paper tested" at only one field site; namely, the LTV/Vought Aero Products Division in Dallas, Texas. From an experimental research perspective, a sample of one may therefore lead to some bias in the experimental (or paper test) results. Thus, in this Section IV of the Final Report the project team has attempted to define the general environment at LTV/VPAD and secondly, to describe a "typical" aerospace and defense contractor. It is belived that LTV/VAPD has an advanced productivity management effort underway and, in this regard, may not be a "typical" aerospace and defense contractor.

### A. LTV/Vought Aero Products Division

The LTV Corporation consists of three companies: LTV Aerospace and Defense Company, LTV Steel Company, and LTV Energy Products. Within the LTV Aerospace and Defense Company, there are four divisions: AM General Division (Livonia, Michigan), Sierra Research Division (Buffalo, NY), Vought Aero Products Division (Dallas, TX), and the Vought Missiles and Advanced Programs Division (Dallas, TX).

The AM General Division is the world leader in military trucks and tactical mobility. Over a 40-year history, AM General has built nearly 1,000,000 military trucks for the U.S. Armed Forces and over 100 friendly foreign nations. AM General offers a wide selection of tactical wheeled vehicles ranging from 1/4-ton to 5-ton trucks.

The Sierra Research Division is a leading developer and manufacturer of electronic systems for military, civil and commercial applications. Innovative achievements in advanced electronic, avionic and digital computer technology include precision guidance and position-tracking radar, aircraft stationkeeping, tactical data links, flight inspection and air navigation.

Targeted for future development are electronic surveillance, position location, integral data transfer and all weather flight aids.

The Vought Missiles and Advanced Programs Division designs and builds rockets, missiles and space systems and is an aerospace industry leader in advanced technology research. The division traces its history back to the Navy Regulus, a submarine-launched missile it developed in the 1950's to give the United States an intercontinental attack capability. Today, its Multiple Launch Rocket System is deployed with the artillery forces of the U.S. Army and will also be fielded with the armies of West Germany, the United Kingdom, France and Italy. The division's Lance missile serves as the primary battlefield artillery weapon for the United States and a number of other NATO countries. Other major programs include an anti-satellite weapon, a candidate for the Joint Tactical Missile System-Army, the Hypervelocity Missile, the Scout space launch vehicle and components for the U.S. space shuttle orbiter.

The Vought Aero Products Division was the actual site for the "paper test" of the three productivity measurement/evaluation models. The division operates facilities consisting of over 6.7 million square feet, principally in Dallas County, Texas. Employing in excess of 14,000 skilled employees, this 68-year old airframe manufacturer has produced more than 15,000 military aircraft and hundreds of major subsections of both military and commercial aerostructures operations.

The division operates from a business base of 80% government products centered on the AFT and AFT-intermediate fuselage sections of the B-1B Air Force bomber, tail and refueling boom components for the KC-10 tanker and renovation of its own A-7 Corsair II attack aircraft for sale to friendly foreign nations. Commercial applications of Vought technology are found in tail sections for Boeing 747, 757 and 767 airliners as well as engine nacelles for the Canadair CL-601 commecial jet aircraft.

The division's strength lies in its highly productive material handling and fabrication techniques. Through extensive innovation in manufacturing technologies, Vought Aero Products has been able to break new ground in production cost-effectiveness and productivity improvement techniques. Practical application is found in the Flexible Machining Cell, an automated mini-factory, considered the most advanced installation of its kind in the world.

Recognition of the need to improve competitive position and modernize facilities, equipment, and systems has induced productivity improvement at Vought Aero Products Division. Productivity improvement at VAPD results from Division Management's proactive support. This support is manifest in an integral part of the Division's annual Development Plan, a detailed Productivity Plan.

Within the Vought Aero Products Division, an integrated productivity measurement, evaluation, control and improvement program is organized under the Vice-President for Manufacturing Development and Support. Organizationally, this function reports to division-level top management. The Manufacturing Development and Support function includes five sub-functions: Facilities, Industrial Engineering, Industrial Modernization (IMOD), Manufacturing Engineering, and Tool Fabrication.

The Industrial Modernization Group is responsible for the development and management of the Productivity Plan that outlines specific targets and projects for implementation to achieve stated objectives and committed productivity improvement. This plan finds concurrence from functional vice presidents and continued progress monitoring via periodic Productivity Council reviews. In this manner, productivity improvement is supported and encouraged in a continuing fashion.

The Director of the IMOD sub-function is reponsible for eight lower level functions, among which is Productivity Requirements. The manager of Productivity Requirements, in turn, has operational responsibility for five major productivity-related tasks: factory analysis, productivity measurement, productivity control, cost/benefit tracking, and IMIP planning/implementation. Thus, at the LTV Aero Products Division, the operational responsibility for the design and execution of an integrated productivity measurement, evaluation, control and improvement program occurs at the departmental level in the division's organizational heirarchy.

The cost structure of Vought Aero Products Division is similar to that found in other aerospace companies. Direct and Overhead Costs are collected into pools for Materials, Manufacturing, Engineering and Logistics. Indirect Costs that support direct functions and activities are collected in overhead accounts. Other Direct Charges, those costs that are directly chargeable to contracts but are not classified as either Direct Labor or Direct Material, are collected into separate accounts. Manufacturing cost additions are defined as the sum of other Direct Charges, Direct and Overhead Costs minus Independent Research and Development Costs. The General and Administrative (G & A) expense pool consists of indirect costs incurred by support organizations. The G & A rate is the ratio of G & A expenses to manufacturing cost additions. Human Resources, Facilities, and Data Processing costs, collected into cost centers, allocate their costs to the pools as indirect costs.

B. Typical Aerospace and Defense Industry Contractor/Subcontractor

There are certain characteristics of a typical Aerospace and Defense Industry Contractor/Subcontractor that influence aspects of the total productivity management process, particularly productivity measurement and incentive methodology, the prime focus of this study contract. These characteristics can be summarized into three main categories -- Products/Technology, Financial/Contracting, and Management.

Product/Technology

The aerospace and defense industry covers a broad range of product/technology from missiles to aircraft, turbine engines, avionics systems, ground based radar, electronic countermeasure devices, ammunition, vehicles, space systems, oceanic systems, ships, guns, etc. Furthermore, this range of products represents manufacturing quantities from one of a kind or limited production of most products up to manufacturing millions per year of ammunition type products. The government is the initiator of the product requirements, controls much of the engineering design and specifications, yet manufacturing of these complex products for the most part is done by private industry.

There is much less program stability compared to commercial industry since the Congress controls the defense budget which is established yearly. Multi-year program procurement is too limited and is further hampered by lengthy implementation periods. Thus, it is more difficult to develop a definitive long term strategic plan, whether for DoD or private industry, than in commercial industry. For the most part, production volume and rates of aerospace and defense industry production are much less than in commercial industry. Furthermore, commercial product and process technology, and specifications are much less complex than in the aerospace and defense industry. The mission of aerospace and defense industry products, for the most part, requires the use of state-of-the-art materials and manufacturing processes to fit more engineering functionality into a smaller space of lighter weight and greater strength and with higher reliability, maintainability and survivability than in commercial industry.

The extensive life cycle through research, design and development of the product complexity of aerospace and defense products necessitates, for the most part, manufacturing initial production prior to completing Full Scale Development (FSD). This practice, in turn, generates numerous and continuous engineering changes that have a significant impact on manufacturing. From DoD's point of view, weapons system requirements are continuously reviewed and improved as new technology or an identified foreign threat changes. These engineering changes often require manufacturing process changes which then must be developed and refined.

Financial/Contracting

The DD633 format required by DoD as an input for price visibility from contractors for major systems procurement provides for the following specific cost account categories:

1. Purchased Materials and Services
    a. Purchased Parts
    b. Subcontracted items
    c. Development materials
2. Procurement Burden
3. Interdivisional Transfers
4. Engineering
    a. labor
    b. overhead
5. Factory
    a. labor
    b. overhead
6. Other Costs
    a. computer
    b. travel
    c. tooling
    d. miscellaneous

Productivity improvement can be reflected in any of the above cost account categories. Factory labor costs, for the most part, are established by work measurement standards and/or parametric estimates. Engineering labor is estimated based on engineering judgment. Purchased materials and services are mostly based on vendor quotations and/or parametric estimates. Rates and factors for labor and material are negotiated yearly based on department budgets. Those non-direct cost department budgets are allocated to direct cost centers and/or purchased material and reflected in the negotiated rates and factors.

The cost of goods sold for Direct Manufacturing Labor is made up of many process demands that comprise work centers, that collectively organize into budget centers that summarize to be cost centers which is the organization level at which pricing is applied. These cost centers at which pricing is applied further aggregate to the total business unit Cost of Goods Sold. The summary of the total budgeted labor hours at the level that the overhead rate is established times the costing rate is the total budgeted cost of goods sold for the business unit. Individual products and/or services that are sold are priced at specific hours times the composite costing rate and/or material plus material burden rate. Actual realized costs for any given process are that which are incurred at each work center, based on individual budget center rates and factors not the composite rates and factors used for pricing.

The historical philosophy of Aerospace Defense Contractors approach to cost accounting has been to collect and allocate projects costs at the macro level. This approach yields aggregate costing rates which tend to neutralize manufacturing process cost realization from a wide range of resource utilization. To provide a most effective evaluation of IMIP project implementation, a more specific allocation of resource utilization is proposed.

The typical contractor might have two hundred budget centers that are summed to six cost centers to yield so-called homogeneous labor rates. Examples of categories within the factory are: test, assembly, fabrication, reliability, support and so on.

BUSINESS UNIT

| COMPOSITE ASSEMBLY RATE | COMPOSITE TEST RATE | COMPOSITE FABRICATION RATE |
|---|---|---|
| • Simple<br>• Average<br>• Complex | • Simple<br>• Average<br>• Complex | • Simple<br>• Average<br>• Complex |

Sample Business Unit Rates Breakdown

Most Aerospace companies have separate costing rates for at least Machine Shop, Assembly and Test Manufacturing Labor as well as Manufacturing Support and Engineering. Within each function are simple, average and complex categories of complexity. In the Machine Shop, a simple workcenter would be a drill press versus turret lathe (average workcenter) and NC machining (complex workcenter). In Assembly, a simple department would be cable assembly versus Printed Wiring Assembly (average complexity department) versus microwave module assembly and/or final assembly (complex department). Similarly, test department complexity ranges from a simple GO-NO GO test to complex test and tune calibration.

In addition, whether it be machine, assembly and/or test labor, a contractor can submit an IMIP to automate a manual process for simple, average and/or complex machine shop, assembly and/or test labor.

In general, DoD contractors allocate costs on the basis of budgeted labor hours. Items of cost such as depreciation, utilities and space are allocated as indirect costs on the basis of budgeted labor hours and are quoted at the same rate for each budget center in the business unit. Technical views of specific cost driving elements are not necessarily synonymous with a business unit's pricing methodology.

Factory overhead rates are composed of accounts that are common to every factory functional area. They will differ with the specific process area level of allocation (in dollar value).

The average factory overhead rate might include the following categorization of accounts:

Direct Labor Costs

- Holiday
- Vacation
- Benefits

Direct Labor Overhead Costs

- Meetings
- Travel
- Training
- Supervision
- Administration
- Dept Support
- Equip. Deprec
- Utilities
- Maintenance
- Space
- Expendables

Allocation Costs

- Management
- Materials
- Technical
- Prod Assurance
- Computer
- Finance
- Miscellaneous

The contractors negotiated rates and factors, estimating and pricing methodology, and cost accounting format need to meet Cost Accounting Standards

(CAS) and specific military specifications and/or standards such as DoD 7000.2 C/SCSC, Mil-Std 1528 Production Management, Mil-Std 1567A Work Measurement, Mil-Std 150 Corrective Action and AFCMD R178.1 CMSEP. The specific methodology used by contractors needs to be specified in the Contractors Disclosure Statement.

Management

There is a broad range of types and size of companies ranging from small job sites of less than 100 people manufacturing a single product for a single customer up to divisions of most of the Fortune 500 companies manufacturing a full range of products for many DoD customers -- Air Force, Army, Navy, NASA, Department of Energy, etc. Thus, a broad range of management leadership, style and culture prevails both within government and private industry. Intensive regulations (DAR and FAR) define the acquisition process. One overriding regulation is the weighted guidelines that control profit by contractors to a fixed percentage of the cost of goods sold. Thus, there is a negative incentive to reduce costs.

There are extensive auditing functions within government DoD to assure that the numerous regulations and standards are being followed. Certainly from a productivity management standpoint, these characteristics have a significant impact on the motive for productivity measurement. There needs to be a champion(s) for productivity improvement both within the contractor/subcontractor, as well as DoD, if significant gains are to be realized.

Increasingly, managers must learn to be situational leaders. There is no one best style or way to manage. The preference for possible outcomes, belief about cause and effect, and standards of desirability vary significantly within and between organizations. In the aerospace and defense industry, much of the performance criteria are controlled by regulations, specifications and are subject to extensive and varied interpretation that makes it difficult to know the right things to be devoting resources towards, know how to accomplish these goals and objectives, and know if and how well these goals and objectives are being accomplished.

LTV/Vought Aero Products Division

LTV/Vought Aero Products Division (LTV/VAPD) is considered to be a large subcontractor manufacturing a wide range of products to all three services. From a product/technology standpoint, LTV/VAPD are manufacturing a wide range of products, of varying product volume and rates of production, of average product complexity. From a manufacturing standpoint, LTV/VAPD have been an industry leader in incorporating its highly productive material handling and fabrication techniques. LTV/VAPD has been an industry leader in the Air Force ICAM program serving as prime contractor for the ICAM conceptual design for computer-integrated-manufacturing project priority 1105.

From a financial/contractor standpoint, LTV/VAPD very much represents a typical aerospace and defense industry contractor. However, from an internal management standpoint, LTV/VAPD are more active and committed to productivity management than the typical aerospace and defense industry contractor. In particular, their application of integrated structured productivity measurement, evaluations and control approach to process selection for productivity improvement. However, they face external factors greater than average in working with their customer(s) to implement their strategy.

# V. APPROACH AND RESULTS

## A. General Approach

Our general approach taken to accomplish the goals and objectives of Phase III was to allow each subcontractor to autonomously coordinate and execute the "paper test" for his specific model. Per our proposal response to the RFP, we decided to actually paper test four models or approaches. Figure V.I indicates the models tested and the researcher/research team responsible for the specific test.

| Model or Approach | Researcher/Research Team Responsible |
|---|---|
| CDEF | Thayer/Price Waterhouse |
| DCF/SSA | Engwall/Westinghouse<br>Agee/VPI-VPC |
| MFPMM | Sink/VPI-VPC |
| LTV/VAPD<br>Integrated<br>Approach | Dhir/LTV-VAPD<br>Sink/VPI-VPC |

Figure V.I Breakdown of Responsibilities for Paper Tests

(NOTE: LTV-VAPD also independently "Paper Tested" each of the three prescribed models.)

Overall project coordination was provided by Dr. Sink and the VPC staff with support from Dr. Tuttle of the MCPQWL. Dr. Agee (VPC) specifically worked with Mrs. Thayer, Mr. Engwall and Mr. Dhir to coordinate the paper tests for the CDEF and DCF/SSA models. Dr. Sink, in addition to providing overall project coordination and management, specifically worked closely with Mr. Dhir and his staff to paper test the MFPMM and the Integrated LTV approach.

Project milestone charts for the overall effort and each model paper test appear in Tables V.2-5. Two progress reports were generated and distributed to the research team, project director, and advisory committee (24 September 1985 and 14 November 1985). Three joint working sessions with all research team members in attendance were held over the six month contract period (26 July 1985, Ft. Belvoir, VA; 14-15 August 1985, LTV, Dallas, TX; 16-17 December 1985, VPI-VPC, Blacksburg, VA). Our first meeting at LTV was designed to develop a plan of attack and to establish some ground rules for the project team to follow. We outlined the final report, established dates for progress reports from the subcontractors, discussed fundamental issues relative to the goals and objectives of the project, and established specific accountabilities and deliverables. In particular, we spent considerable time discussing the difference between a "paper test" and a "field test." Our conclusion was that the paper test should evaluate the models, on paper, addressing specific questions raised in the RFP. We did not view development or extensive data analysis with the models as within the scope of Phase III.

The details of our general approach are reflected in what follows.

B. Description of Each Model

1. Description of Price Waterhouse's Cost Definition Methodology (CDEF)

Price Waterhouse has developed its CDEF Methodology as an approach for preparing performance and cost baseline data in support of commercial factory modernization or Department of Defense Industrial Modernization Incentives Programs - IMIP's. CDEF utilizes a top-down analysis technique which facilitates the identification of appropriate performance and cost measurement criteria, selection of improvement opportunities, and economic justification of identified investments. The CDEF methodology has been developed as a result of work performed for several Price Waterhouse clients; therefore, it has been field developed and found workable.

The CDEF Methodology has been tailored to accommodate several objectives:

- o Provide an auditable, consistent approach for performance and cost-benefit analysis and tracking.
- o Identify the true costs of a manufacturing process to clearly establish savings criteria.
- o Provide outputs that remain reliable when product mix and volume changes over time.
- o Provide a mechanism for evaluating project and compensating for project risk.

Price Waterhouse has developed nine criteria that form the basic elements of the CDEF Methodology. In addition to these nine criteria, a software tool, the Automated Cost Baseline Generator (ACBG) has been developed to ease the level of calculating that must be performed when developing cost and performance baselines. The nine criteria are as follows:

1) Has a functional structure been used?

   The node tree diagram shown in Figure V.1 represents a typical aerospace "top-down" approach for identifying manufacturing activities. By documenting all manufacturing activities within a project's scope, greater assurance is provided that total cost is captured and that significant performance measurements are identified.

2) Have Function Groups been identified?

   Function Groups are defined as the group(s) of low level nodes that are impacted by a given technology improvement program.

3) Have the total costs for the baseline period been "mapped" against the functional (top down) structure?

   The overlay of the total operating costs against the functional structure establishes input/output cost measures.

4) Has a comprehensive Manufacturing Cost Model been identified?

   A typical manufacturing cost model groups cost by material segments, labor segments and overhead and support segments.

5) Have Critical Success Factors and the related performance measures been identified?

   Critical Success Factors are defined as those performance measurement criteria that must be satisfied if the expected goals of a given project are to be attained.

6) Have "As Is" and "To Be" cost and performance baselines been established?

   The primary reason for developing baselines is to provide a mechanism for monitoring and analyzing cost and performance behavior pattern changes as a given technology is implemented.

7) Has project risk been considered?

   By identifying and documenting the risk aspects of the project, alternative scenarios for controlling it can be prepared.

8) Have the synergistic impacts of the technology improvements been considered?

   The concept of synergistic identification is applicable when multiple projects with multiple technologies are being implemented simultaneously within a single program.

9) Has a benefits tracking plan been developed?

   The benefits tracking plan "closes the loop" of the cost-benefit process and helps assure that what was planned is realized.

Additional information regarding the details of CDEF is provided in the appendix to this volume.

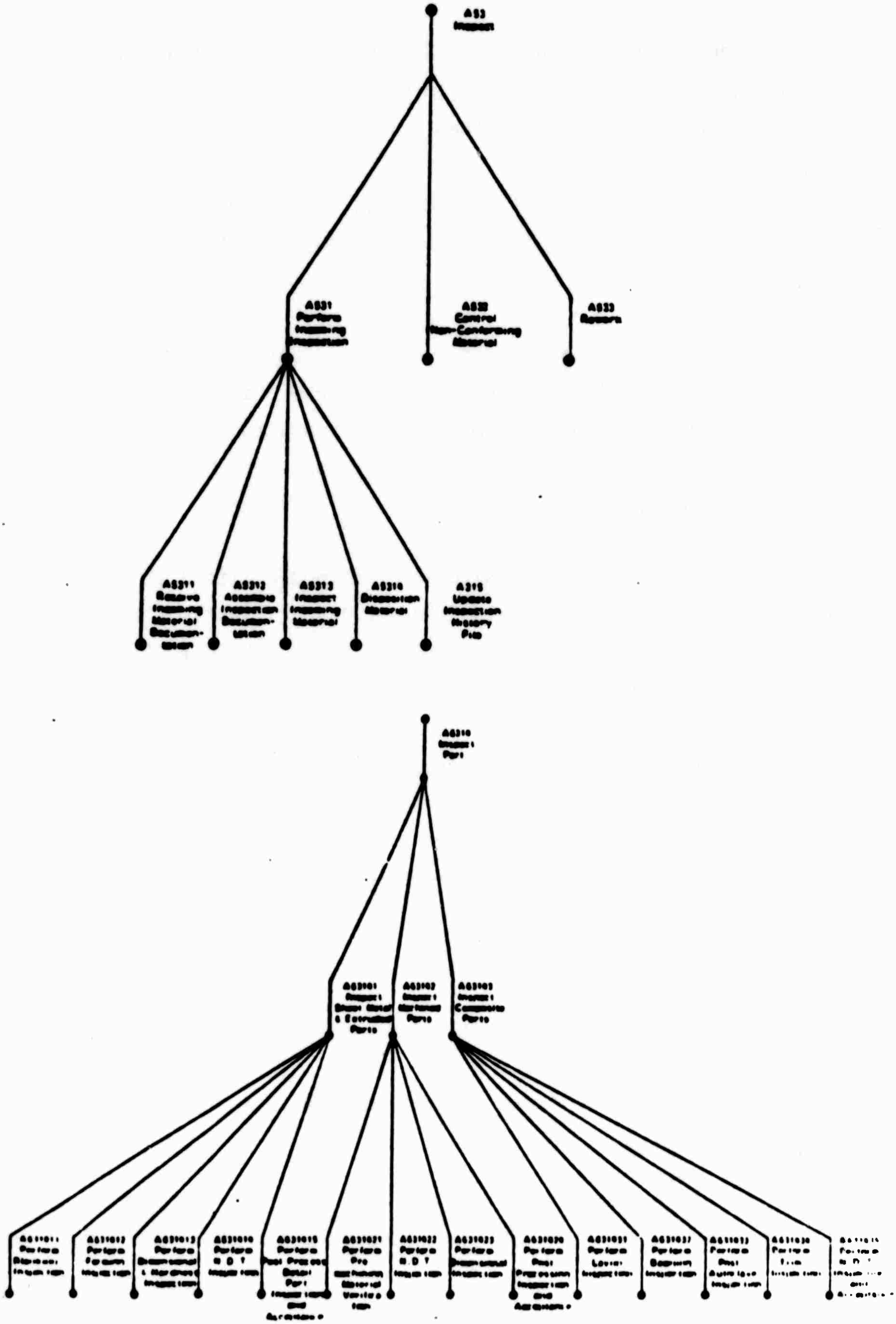


Figure V.1

## 2. DCF/SSA

The objective of the DCF/SSA is to provide a basis for analyzing a proposed Industrial Modernization Incentives Program (IMIP) business arrangement for the contractor, the Department of Defense (DoD), and the Government.

There are two versions of application of the DCF model philosophy included herein: the Westinghouse version and the Logistics Management Institute (LMI) version.

The Westinghouse DCF/SSA model was developed for implementation of the USAF Electronic Systems Division/Westinghouse Get PRICE Program which was initiated July 31, 1981. The LMI DCF/SSA model was prepared pursuant to DoD Contract No. MDA903-81-C-0166 January, 1984 for performing discounted cash flow analysis of IMIP proposals.

While the internal rate of return (IRR) calculation method utilized in both models is basically identical, the two have inherent disparities in the approach to the net cash flow calculations. However the net affect of each model will -yield similar results given identical input.

The purpose of the DCF/SSA is to provide an evaluation tool for capital investment decisions by measuring a projected rate of return of proposed investment projects. An acceptable return rate is compared to the calculated net cash flow rate of return projection to ascertain financial feasibility.

### INPUT

Required inputs include projected investment and savings applicable to the project. Investment will include:

Project expense - annual expenditures for design, development, support, follow, etc.

Project capital - annual expenditures for the various categories of equipments as well as land, buildings, etc.

Savings will include three categories and must be identified in annual increments:

- Total Government savings
- Savings applicable to programs identified as participants in sharing.
- Commercial program savings

## OUTPUT

The salient output feature of the DCF/SSA model is the Net Cash Flow per annum. The output elements of the model's net cash flow line are:

1) CAS 409 Depreciation Recovery - straight line depreciation recovery (CAS409).

2) Expense Recovery-
   - The model accounts for Recovery through labor rates of Expenses invested, discounted for a level of Commercial Business included in the business base.

3) Cost of Money (CAS 414)
   Utilizing the U.S. Department of the Treasury published rates, the model accounts for the facilities capital investment cost recovery discounted by the level of commercial business included in the business base.

4) Profit on Recoverables
   The model allows for a percentage recovery of costs recovered at the direct cost level discounted for commercial business in the business base.

5) Loss on Savings
   The Model accounts for the level of profit not realized due to the substantial level of savings generated. The average government savings per year times the negative value of the appropriate weighted guide lines profit level yields this value.

6) Retained Savings

The model provides for retention of savings allocated to any in process fixed price government contracts as well as any commercial business included in the business base.

Refer to the Appendix of this Volume I for detailed descriptions of each of the two models.

### 3. Multi-Factor Productivity Measurement Model (MFPMM)

The Multi-Factor Productivity Measurement Model is designed as a decision/management support system to provide management with data and information about how a system is performing. For information on the background, development and evolution of the model see Sink, 1985. The model can be and is being utilized: (1) to obtain an overall, integrated measure and trend for productivity at the firm, division or plant level; (2) to provide an analytical audit of past performance; (3) for budget control, analysis, and projection evaluation; (4) for common price financial statements; (5) to assess and evaluate bottom-line impact on profits of various productivity and price-recovery intervention; (6) to track the impact of various specific productivity improvement interventions; (7) to provide the measurement tool and base for gainsharing systems, (8) to assist in setting and achieving productivity objectives and to integrate with general strategic planning, relative to capacity utilization, efficiency, marketing efforts, cost management, resource utilization, etc.

The basic model, over the years, has been and is known by many names. For example, various versions are called: REALST, Total Factor Productivity Measurement Model, Total Productivity Model. The specific model tested in this project is a version called the Multi-Factor Productivity Measurement Model developed by Dr. D. Scott Sink and associates over the past seven years.

The description of the MFPMM that follows is extracted from a recently published book written by Dr. Sink. The excerpt is reprinted with permission from John Wiley and Sons.

## *MFPMM Basics*

As we have mentioned earlier, productivity measurement can be impeded by product variety and the multiplicity of various resources utilized. Person-hours cannot be combined with tons of steel, dollars of capital equipment, kilowatt-hours, and so forth for a resource total. Nor could a Westinghouse or a General Electric add up the number of motors, refrigerators, electrical components, and so forth to get a measure of total product. The dollar, in the case of the United States, is a convenient common denominator.

Since productivity gains or losses are distributed via the price system (the customer, stockholder, owner, and employee benefit or lose according to shifts in productivity), it seems appropriate to use the yardstick of that system—money—to analyze the distribution. However, the dollar or any other currency is, particularly in the current economic period, a variable standard. Therefore, in order to use the dollar as an aggregating measure, the variability needs to be taken out (Davis, 1955). One major characteristic of the model to be presented is a requirement for and incorporation of a "revaluing," devaluing, or indexing mechanism. In essence, the model "partials out" or holds constant price and cost changes over time. This is accomplished either with the actual revaluing of outputs and/or inputs prior to use in the model or by selecting a base period for the model and "automatically" indexing prices and costs back to that period.

The basic concept of productivity measurement utilizing constant value prices and costs is presented in Table 5.2. As one can see, by revaluing or indexing to base year values, the analysis simply partials out or removes the influence in price and cost changes from the base year or period to the current year or period. What remains is the constant dollar value of output and input resources consumed. When these two values are compared for the base year, we establish a productivity ratio labeled output per dollar of input. When the current year or period productivity ratio is compared to the base year or period, we establish a productivity index. This table and these measures of productivity are consistent with the development presented in Chapter 2.

From a pragmatic business sense, the underlying purpose of productivity measurement and evaluation is to improve business operations and competitive position so as to enhance accomplishment of longer-term goals of survival, profitability, missions, effectiveness, and so forth. "Without productivity objectives, a business does not have direction. Without productivity measurement, it does not have control" (Drucker, 1980). The MFPMM can be utilized to measure productivity change in labor, materials, energy, and even capital, although it is not explicitly treated in this book. It can also be used to measure the effects of these changes separately as well as in aggregate on corresponding change in business profitability or, in the case of public-sector nonprofit firms, in budget maintenance. As van Loggerenberg and Cucchiaro (1982) point out, this "new" technique can be utilized to

1. Monitor historical productivity performance and measure how much, in dollars, profits were affected by productivity growth or decline
2. Evaluate company profit plans to assess and determine the acceptbility and reasonableness or productivity changes in relation to those plans

**Table 5.2 Illustrative Calculation of Productivity Change Using Output and Input Data Revalued at Constant Prices**
(Output and input totals in millions of dollars)

| ITEM | BASE YEAR | GIVEN YEAR REVALUED AT BASE-YEAR PRICES |
|---|---|---|
| *Case A. Increase in Productivity: Profits Earned Both Years* | | |
| Value of output | $200 | $275 |
| Cost of input (including profit at base-year rate) | $200 | $250 |
| Output per dollar of input | $ 1.00 | $ 1.10 |
| Productivity change, given/base year: | | |
| Percentage | | + 10 percent |
| Per dollar of input | | +$ 0.10 percent |
| Total dollars | | +$ 25 |
| *Case B. Increase in Productivity: Losses Incurred Both Years* | | |
| Value of output | $170 | $252 |
| Cost of input | $200 | $280 |
| Output per dollar of input | $ 0.85 | $ 0.90 |
| Productivity change, given/base year: | | |
| Percentage | | + 5.9 percent |
| Per dollar of input | | +$ 0.05 |
| Total dollars | | +$ 14 |
| *Case C. Decrease in Productivity: Profits Earned Both Years* | | |
| Value of output | $200 | $228 |
| Cost of input (including profit at base-year rate) | $200 | $240 |
| Output per dollar of input | $ 1.00 | $ 0.95 |
| Productivity change, given/base year: | | |
| Percentage | | − 5 percent |
| Per dollar of input | | −$ 0.05 |
| Total dollars | | −$ 12 |

SOURCE: H.S. Davis, *Productivity Accounting*, 1955. Reprinted with permission.

3. Measure the extent to which the firm's productivity performance is strengthening or weakening its overall competitive position relative to its peer group(s)

These three uses for the MFPMM in addition to the eight additional uses mentioned earlier represent significant benefits accruable from this model.

An organization's financial performance (one of the seven measures of performance previously mentioned) is a result of interactions of a wide variety of controllable and uncontrollable factors. Managers in organizational systems attempt to improve performance by managing (allocating, utilizing, controlling, delegating, and so forth) resources under their control while being constrained or influenced by the uncontrollable factors. Typical uncontrollable factors are

- economic environment
- industry/market growth or decline
- resource prices (costs), particularly in an inflationary period
- rates of inflation for product prices versus resource costs
- budget allocation
- organizational processes and procedures

Typical controllable factors are

- technological innovation
- resource substitutions
- training and motivaton of employees
- asset redeployment
- resource quality

It is interesting to note that a number of variables will influence or determine which specific factors a given manager preceives as controllable or uncontrollable. Such variables as position with the firm, personality type, leadership style, and locus of control will shape the manager's perceptions. It would seem reasonable that a manager's actual behaviors are affected more directly and strongly by perceptions than "reality." Managers today view themselves as being significantly constrained by uncontrollable factors. This is a potentially consequential dilemma with respect to prospects for productivity improvement.

The MFPMM makes it possible to measure explicitly, in terms of dollars the profit impacts of these uncontrollable as well as controllable factors and to determine and analyze how various management strategies could increase or decrease profitability. Fundamentally, profit change comes about because of a difference between revenues and costs. If revenues increase faster than costs, there would obviously be a positive change in profits (see Figure 5.1). Yet revenues and costs do not always present a complete picture because of underlying complex relationships between controllable and uncontrollable factors. Therefore, as Davis, and Scott (1950) before him, pointed out, "[t]he net profit figure alone is an inadequate basis for judgment as to whether industrial operations are being carried out efficiently and labour and materials utilized effectively; it may merely tell us that a satisfactory balance has been struck between the value received and the value given." With essentially the same basic accounting information used to calculate revenues and costs, however, it is possible to use the MFPMM to gain additional and significantly more detailed insight into what is driving profits.

Column 1 of Figure 5.2 depicts, as presented in Chapter 2, the basic productivity index relationship, a change in output quantities over a change in resource quantities. In every organizational system, there exists a unique productivity index for each resource. Column 2 depicts what has been called a "price recovery

$$\frac{\text{Total Revenue (TR)}}{\text{Total Cost (TC)}} = \frac{\sum_{i=1}^{n} Q_i^O p_i^O}{\sum_{i=1}^{m} Q_i^I p_i^I} = \text{a measure of profitability}$$

where: $Q_i^O$ = quantities of type $i$ output (superscript $O$)
$p_i^O$ = the unit price for each output type
$Q_i^I$ = Quantities of type $i$ input type (superscript $I$)
$p_i^I$ = the unit cost for each input type
$n$ = the number of different types of output
$m$ = the number of different types of input

$$\frac{\Delta TR}{\Delta TC} = \frac{\dfrac{\left(\sum_{i=1}^{n} Q_i^O p_i^O\right)\text{ period}_2}{\left(\sum_{i=1}^{n} Q_i^O p_i^O\right)\text{ period}_1}}{\dfrac{\left(\sum_{i=1}^{m} Q_i^I p_i^I\right)\text{ period}_2}{\left(\sum_{i=1}^{m} Q_i^I p_i^I\right)\text{ period}_1}} = \text{measure of change in profitability}$$

**Figure 5.1 Profitability Assessment**

$$\begin{array}{ccccc}
\Delta\text{ in output quantity} & \times & \Delta\text{ output price} & = & \Delta\text{ revenue} \\
\| & & \| & & \| \\
\dfrac{\sum_{i=1}^{n} [(Q_i^O)\text{ period}_2}{\sum_{i=1}^{n} [(Q_i^O)\text{ period}_1} & \times & \dfrac{(p_i^O)\text{ period}_2]}{(p_i^O)\text{ period}_1]} & = & \dfrac{\text{TR period}_2}{\text{TR period}_1} \\
\hline
\dfrac{\sum_{i=1}^{m} [(Q_i^I)\text{ period}_2}{\sum_{i=1}^{m} [(Q_i^I)\text{ period}_1} & \times & \dfrac{(p_i^I)\text{ period}_2]}{(p_i^I)\text{ period}_1]} & & \dfrac{\text{TC period}_2}{\text{TC period}_1} \\
\| & & \| & & \| \\
\Delta\text{ resource quantity} & \times & \Delta\text{ resource costs (prices)} & = & \Delta\text{ cost} \\
\text{Column 1} & & \text{Column 2} & & \text{Column 3} \\
\text{Productivity} & \times & \text{“Price Recovery”} & = & \text{Profitability}
\end{array}$$

**Figure 5.2 Productivity, Price Recovery, Profitability Relationship.**

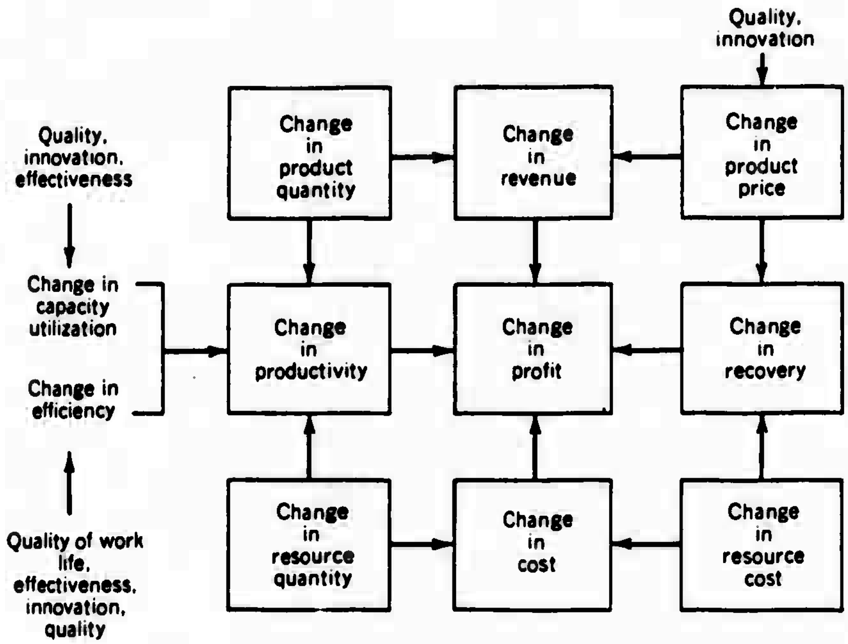



**Figure 5.3 Basic Factors and Interrelationships Contributing to Performance** (Adapted from B. J. van Loggerenberg and S. J. Cucchiaro, "Productivity Measurement and the Bottom Line," *National Productivity Review*, Winter 1981–82)

index." The price recovery index is a change in output prices over a change in resource costs (prices). Column 3 reflects the profitability index, a change in revenues over a change in costs. Note that if all other factors are held constant, namely prices and costs, a positive change in the productivity index will cause or translate into a positive change in profits. Similarly, if quantities are held constant and the price recovery index is positive (output prices increase at a faster rate than resource costs), then profits, at least in the short run, will be positive. Figure 5.3, adapted from van Loggerenberg and Cucchiaro, is another representation of these relationships.

The MFPMM reflects an attempt to add to and enhance conventional profit analysis represented by Column 3. The ability to evaluate profitability changes in terms of where they come from and how they were caused is increasingly coming to be viewed as an important control system element. Similar to redesigning the control panel for an aircraft, we are beginning to see management in the United States reevaluate the instruments, dials, knobs, and controls in the control system for organizations.

## *Description of the MFPMM*

Table 5.3 depicts the format for the MFPMM. The easiest way to describe the model is to work through the format with an example, moving from left to right

## Table 5.3 Multiple Productivity Measurement Model Format (VPI/VPC Version MFPMM)

| | Period 1 | | | Period 2 | | | Weighted Change Ratios | | | Cost/Revenue Ratios | | Productivity Ratios | | Weighted Performance Indexes | | | Dollar Effects on Profits | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity $Q_1$ | Price $P_1$ | Value $(Q_1)(P_1)$ | Quantity $Q_2$ | Price $P_2$ | Value $(Q_2)(P_2)$ | $\frac{Q_2P_1}{Q_1P_1}$ | $\frac{Q_2P_2}{Q_2P_1}$ | $\frac{Q_2P_2}{Q_1P_1}$ | $\frac{I_{i1}}{\Sigma(Q_1)(P_1)}$ | $\frac{I_{i2}}{\Sigma(Q_2)(P_2)}$ | Period 1 | Period 2 | Change in Productivity (7/7) | Change in Price Recovery [illegible] | Change in Profitability [illegible] | Change in Productivity | Change in Price Recovery | Change in Profitability |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| [illegible] | | | | | | | | | | | | | | | | | | | |

or from Column 1 to Column 19. For the purpose of instructional clarity, a simple example involving a fiberglass boat manufacturer is utilized to explain and "teach"the workings of MFPMM.

## *Columns 1–6*

The first six columns of the MFPMM are data input. Column 1 represents quantities of outputs the organizational system produced and/or sold and quantities of input resources consumed in order to produce those outputs for period 1. As mentioned previously, period 1 in this model will be designated as a base period. Selection of a base period is primarily a matter of selecting a representative period in time against which you wish to compare current period performance. It might be a period of time in 1967, which just happens to be the base year utilized in the consumer price index. Or it might be a unique period in time representative of current business conditions. The base period designation can be "standards" or even simply last period. However, note that if one selects the last period as the base period and hence allows the base period to change each time the current period moves ahead, then the built-in indexing mechanism in the model is negated. In such a case, an external indexing mechanism will have to be imposed. This involves utilizing a published index, such as the producers price index or the GNP index. For more detail on indexing, refer to Anderson, Sweeney, and Williams (1981) and American Productivity Center (1978).

Recall also that the organizational system boundaries or unit of analysis for this model are flexible. A productivity process modeling exercise should precede any attempted development of an application of the MFPMM. This will ensure accurate definition of unit of analysis, inputs, outputs, and outcomes. Another parameter to be determined prior to application of this model is the length of the analysis period. Depending on decision-maker needs and interests, data availability, product cycle time, and so forth, the length might be almost any period of time (weekly, monthly, quarterly, semiannually, annually). When determining the length of the period, keep in mind your data collection needs and data matching requirements. The goal is to match outputs produced during a given period to the input resources utilized during that same period in time.

So, Column 1 represents quantities of outputs produced during the base period and quantities of inputs utilized to produce those outputs during the same base period. Table 5.4 depicts data for the base period of our boat company example. Note that in period 1 (base period) the company produced 50 Boat *A*s and 30 Boat *B*s, and utilized 320 units (in this case, hours) of management labor, 800 units (hours) of fiberglass labor, 1120 units (hours) of assembly labor, 2200 units of fiberglass, 750 units of wood, 8000 units (in this case, KWHs) of electricity, and 100 units (in this case, MCF) of gas. Note also that the scale or units utilized for outputs and inputs is a decision that can be made by the analyst. In addition, the number and class of categories, types (subcategories), and levels (sub-sub-categories) in inputs and outputs (the rows in the model) is a decision that can

**Table 5.4 LINPRIM Boat Company Example (VPI/VPC Version MFPMM): Period 1 (Columns 1–6)**

| | PERIOD 1 | | | PERIOD 2 | | |
|---|---|---|---|---|---|---|
| | (1) QUANTITY | (2) PRICE | (3) VALUE | (4) QUANTITY | (5) PRICE | (6) VALUE |
| BOAT A | 50.0 | 5000.00 | 250000.00 | 70.0 | 5500.00 | 385000.00 |
| BOAT B | 30.0 | 10000.00 | 300000.00 | 35.0 | 12000.00 | 420000.00 |
| TOTAL OUTPUTS | | | 550000.00 | | | 805000.00 |
| LABOR MANAGEMENT | 320.0 | 20.00 | 6400.00 | 304.0 | 22.00 | 6688.00 |
| LABOR GLASS | 800.0 | 8.00 | 6400.00 | 760.0 | 9.00 | 6840.00 |
| LABOR ASSEMBLY | 1120.0 | 6.00 | 6720.00 | 1064.0 | 7.00 | 7448.00 |
| TOTAL LABOR | | | 19520.00 | | | 20976.00 |
| FIBERGLASS | 2200.0 | 50.00 | 110000.00 | 3000.0 | 85.00 | 255000.00 |
| WOOD | 750.0 | 3.00 | 2250.00 | 1000.0 | 3.00 | 3000.00 |
| TOTAL MATERIALS | | | 112250.00 | | | 258000.00 |
| ELECTRICITY | 8000.0 | 0.10 | 800.00 | 8200.0 | 0.10 | 820.00 |
| NATURAL GAS | 100.0 | 4.00 | 400.00 | 90.0 | 4.00 | 360.00 |
| TOTAL ENERGY | | | 1200.00 | | | 1180.00 |
| TOTAL INPUTS | | | 132970.00 | | | 280156.00 |

be made by either the analyst, decision maker(s), or other users of the model. For example, one could break out, by level, management labor (president, supervisor, plant manager, and so forth). The model will accommodate at least three levels (class, type, and level) of output and input. Since the model is computerized, it can handle, depending on how it is programmed, almost any number of rows. For example, the VPI/VPC version of the model for a HP3000 system is programmed to accept up to 100 row elements for each category (output, labor, energy, materials). Minicomputer programs of the model, such as on the IBM PC with 126K storage, have capacity for slightly more than 50 total row elements.

Column 2 represents the unit price for outputs and unit cost for inputs during period 1 (base period). From Table 5.4 you can see that Boat *A* sold for $5000, and Boat *B* sold for $10,000; management labor cost $20.00 per unit (hour); fiberglass labor cost $8.00 per unit (hour); assembly labor cost $6.00 per unit (hour); fiberglass cost $50.00 per unit; wood cost $3.00 per unit; electricity cost $.10 per unit (KWH); and gas cost $4.00 per unit (MCF). Note that since the analyst or user of the model can define the unit of measurement to be utilized for each output and input, the unit price and cost is also controllable. For instance, labor cost can reflect base salary, or wage rate plus bonuses or benefit calculations. The only requirement is that the unit cost remain consistent with the units of quantity.

Column 3 reflects the value (quantity × price) for each row element (outputs and inputs). Therefore, column 3 represents revenues for outputs and costs for inputs. This column is calculated automatically by the programmed version of this model. So, from Table 5.4 you can see that this company had revenues of $250,000 from sales of Boat *A*s and $300,000 from sales of Boat *B*s for a total revenue figure of $550,000; at the same time, cost for management labor was $6400; fiberglass labor, $6400; assembly labor $6720; fiberglass, $110,000; wood, $2250; electricity, $800; and gas, $400. Again, Column 3 is automatically calculated in the programmed version of this model.

Columns 4–6 are the same as columns 1–3 except that they are data for period 2 or the current period. Again, columns 4 and 5 are the data input requirements and column 6 is simply column 4 × column 5. From Table 5.4 you can see the following:

1. Boat *A* production went from 50 in the base period to 70 in current period; the price for Boat *A* went from $5000 in period 1 to $5500 current period.

2. The company utilized 16 less units (hours) of management labor but increased the cost for that category of labor from $20.00 to $22.00.

3. Fiberglass utilization increased by 800 units, and the unit cost rose from $50.00 to $85.00.

Interpretation of other changes should by now be evident and self-explanatory.

These first six columns of the MFPMM, in particular Columns 1, 2, 4, and 5, reflect data input required to "run" the model. Data availability appears not to be a critical roadblock to successful implementation of this model. Experience suggests that the basic data required to run this model are typically available from most accounting or comptroller departments. Many decisions and finer points to the actual development of an application of this model could be discussed now. However, it may be more effective to continue this tutorial on this simple example and reserve discussion of finer points until later in this Chapter.

## *Columns 7–9*

The next three columns in the MFPMM are titled "Weighted Change Ratios." The basic purpose of these columns and, in particular, the formula calculations is to determine:

*Column 7:* Price-weighted and base period price indexed changes in quantities. Essentially, Column 7 partials out or holds constant the effect of prices and just examines the price-weighted changes in quantities of outputs and inputs. (See Figure 5.4 for the formula for Column 7.)

*Column 8:* Quantity-weighted and current period indexed changes in unit prices and unit costs. Essentially, Column 8 partials out or holds constant the changes in quantities of outputs and inputs and just examines the changes in unit prices and unit costs from period 1 to period 2. (See Figure 5.4 for the formula for Column 8.)

$$\text{Column 7: } \frac{\sum_{i=1}^{n}(Q_{i2})(p_{i1})}{\sum_{i=1}^{n}(Q_{i1})(p_{i1})}$$

$$\text{Column 8: } \frac{\sum_{i=1}^{n}(Q_{i2})(p_{i2})}{\sum_{i=1}^{n}(Q_{i2})(p_{i1})}$$

$$\text{Column 9: } \frac{\sum_{i=1}^{n}(Q_{i2})(p_{i2})}{\sum_{i=1}^{n}(Q_{i1})(p_{i1})} \text{ or Column 7} \times \text{Column 8}$$

**Figure 5.4 Weighted-Change Ratio Formulas for Outputs and Inputs**

*Column 9:* Examines the simultaneous impact of changes in price and quantity from period 1 to period 2 for each row in the model. (See Figure 5.4 for the formula for Column 9.)

From Column 7 (Table 5.5) it can be seen that

1. In period 2, 40 percent more Boat *A*s were produced than in period 1.

$$\frac{Q_2P_1{}^*}{Q_1P_1} = \frac{70(5000)}{50(5000)} = 1.40$$

2. In period 2, 16.67 percent more Boat *B*s were produced than in period 1.

$$\frac{35(10000)}{30(10000)} = 1.1667$$

3. In period 2, 27.27 percent more boats of types *A* and *B* were produced.

$$\frac{\Sigma Q_2P_1{}^*}{\Sigma Q_1P_1} = \frac{70(5000) + 35(10000)}{50(5000) + 30(10000)} = 1.2727$$

4. In period 2, 5 percent less labor was utilized than in period 1.

$$\frac{304(20) + 760(8) + 1064(6)}{320(20) + 800(8) + 1120(6)} = 0.95$$

*Shorthand formula notation.

**Table 5.5 LINPRIM Boat Company Example (VPI/VPC Version MFPMM): Columns 7–11**

| | WEIGHTED CHANGE RATIOS (7) QUANTITY | (8) PRICE | (9) VALUE | COST/REVENUE RATIOS (10) PERIOD 1 | (11) PERIOD 2 | PRODUCTIVITY RATIOS (12) PERIOD 1 | (13) PERIOD 2 |
|---|---|---|---|---|---|---|---|
| BOAT A | 1.4000 | 1.1000 | 1.540 | | | | |
| BOAT B | 1.1667 | 1.2000 | 1.400 | | | | |
| TOTAL OUTPUTS | 1.2727 | 1.1500 | 1.464 | | | | |
| LABOR MANAGEMENT | 0.9500 | 1.1000 | 1.045 | 0.0116 | 0.0083 | 85.94 | 115.13 |
| LABOR GLASS | 0.9500 | 1.1250 | 1.069 | 0.0116 | 0.0085 | 85.94 | 115.13 |
| LABOR ASSEMBLY | 0.9500 | 1.1667 | 1.108 | 0.0122 | 0.0093 | 81.85 | 109.65 |
| TOTAL LABOR | 0.9500 | 1.1311 | 1.075 | 0.0355 | 0.0261 | 28.18 | 37.75 |
| FIBERGLASS | 1.3636 | 1.7000 | 2.318 | 0.2000 | 0.3168 | 5.00 | 4.67 |
| WOOD | 1.3333 | 1.0000 | 1.333 | 0.0041 | 0.0037 | 244.44 | 233.33 |
| TOTAL MATERIALS | 1.3630 | 1.6863 | 2.298 | 0.2041 | 0.3205 | 4.90 | 4.58 |
| ELECTRICITY | 1.0250 | 1.0000 | 1.025 | 0.0015 | 0.0010 | 687.50 | 853.66 |
| NATURAL GAS | 0.9000 | 1.0000 | 0.900 | 0.0007 | 0.0004 | 1375.00 | 1944.44 |
| TOTAL ENERGY | 0.9833 | 1.0000 | 0.983 | 0.0022 | 0.0015 | 458.33 | 593.22 |
| TOTAL INPUTS | 1.2990 | 1.6220 | 2.107 | 0.2418 | 0.3480 | 4.14 | 4.05 |

5. In period 2, 36.36 percent more fiberglass was utilized than in period 1.

$$\frac{Q_2P_1^*}{Q_1P_1} = \frac{3000(50)}{2200(50)} = 1.3636$$

6. In period 2, 33.33 percent more wood was utilized than in period 1.

$$\frac{1000(3)}{750(3)} = 1.3333$$

7. In period 2, 36.3 percent more materials were utilized than in period 1.

$$\frac{3000(50) + 1000(3)}{2200(50) + 750(3)} = 1.3630$$

*Shorthand formula notation.

8. Total price-weighted and indexed change in inputs utilization was 29.90 percent.

$$\frac{304(20) + 760(8) + 1064(6) + 3000(50) + 1000(3) + 8200(.10) + 90(4)}{320(20) + 800(8) + 1120(6) + 2200(50) + 750(3) + 8000(.10) + 100(4)}$$

Hence, Column 7 simply tells us the rate of price-weighted quantity change with prices and costs held constant at period 1 levels.

From Column 8 it can be seen that

1. The prices of Boat *A* went up 10 percent.

$$\frac{Q_2P_2^*}{Q_2P_1} = \frac{70(5500)}{70(5000)} = 1.10$$

2. The quantity-weighted average price change for Boats *A* and *B* was 15 percent.

$$\frac{\Sigma Q_2P_2^*}{\Sigma Q_2P_1} = \frac{70(5500) + 35(12000)}{70(5000) + 35(10000)} = 1.15$$

3. Management labor unit cost increased 10 percent

$$\frac{304(22)}{304(20)} = 1.10$$

4. Quantity-weighted average cost increase for labor was 13.11 percent.

$$\frac{304(22) + 760(9) + 1064(7)}{304(20) + 760(8) + 1064(6)} = 1.1311$$

5. Fiberglass unit cost increased 70 percent

$$\frac{3000(85)}{3000(50)} = 1.70$$

*Shorthand formula notation.

6. Quantity-weighted average cost increase for materials was 68.63 percent.

$$\frac{3000(85) + 1000(3)}{3000(50) + 1000(3)} = 1.6863$$

7. There were no changes in the price of gas or electricity.

$$\frac{8200(.10) + 90(4)}{8200(.10) + 90(4)} = 1.00$$

8. Total quantity-weighted change in input costs was 62.20 percent.

$$\frac{304(22) + 760(9) + 1064(7) + 3000(85) + 1000(3) + 8200(.10) + 90(4)}{304(20) + 760(8) + 1064(6) + 3000(50) + 1000(3) + 8200(.10) + 90(4)}$$

Hence, Column 8 simply indicates the rate of quantity-weighted price and cost change with quantities of outputs and inputs held constant at period 2 levels.
From Column 9 it can be seen that

1. Revenues from Boat *A* increased 54 percent.

$$\frac{Q_2P_2^*}{Q_1P_1} = \frac{70(5500)}{50(5000)} = 1.54$$

2. Combined impact on revenue change from period 1 to period 2 from both Boat *A* and Boat *B* was 46.36 percent.

$$\frac{\Sigma Q_2P_2^*}{\Sigma Q_1P_1} = \frac{70(5500) + 35(12000)}{50(5000) + 30(10000)} = 1.4636$$

3. Total labor cost increased 7.46 percent from period 1 to period 2.

$$\frac{304(22) + 760(9) + 1064(7)}{320(20) + 800(8) + 1120(6)} = 1.0746$$

*Shorthand formula notation.

4. Total input costs increased 110.69 percent.

$$\frac{304(22) + 760(9) + 1064(7) + 3000(85) + 1000(3) + 8000(.10) + 90(4)}{320(20) + 800(8) + 1120(6) + 2200(50) + 750(3) + 8000(.10) + 100(4)}$$

Hence, Column 9 simply indicates the rate of change of revenues and costs (simultaneous changes in prices, costs, and quantities of outputs and inputs).

## *Columns 10 and 11*

Columns 10 and 11 are labeled "Cost/Revenue Ratios." They indicate the ratio of input row elements for Columns 3 and 6. The formula for these columns appears in Figure 5.5. Note that Column 10 is the cost-to-revenue ratio for period 1 and Column 11 is the cost-to-revenue ratio for period 2.

From Column 10 one can observe that management labor costs (Column 3) represent 1.16 percent of total revenues in period 1 (\$6400/\$550,000). Similarly, total labor costs represent 3.55 percent of total revenues, fiberglass costs reflect 20 percent of total revenues, and total input costs reflect 24.18 percent of total revenues. Note that since this model is not attempting to be a total factor productivity measurement model, there is no way to tell directly whether the 75.82 percent of remaining revenues is all profits or consumed by other input resource costs not captured in this model. Note also that the information in these two columns will very likely be already available and familiar to most managers. Most managers are knowledgeable about certain cost categories as a percentage of either total costs, total revenues, or some other aggregate budget number.

The purpose of these two columns is not to provide new information but to integrate this information into the MFPMM so as to provide a manager with

$$\text{Column 10: } \frac{I_{ij1}}{\sum_{i=1}^{n}(O_{i1})(p_{i1})} = \frac{\text{Input elements, column 3}}{\text{Total, column 3}}$$

$$\text{Column 11: } \frac{I_{ij2}}{\sum_{i=1}^{n}(O_{i2})(p_{i2})} = \frac{\text{Input elements, column 6}}{\text{Total column 6}}$$

$$\text{Column 12: } \frac{\sum_{i=1}^{n}(O_{i1})(p_{i1})}{(I_{ij1})(p_{ij1})} = \frac{\text{Total, column 3}}{\text{Input elements, column 6}}$$

$$\text{Column 13: } \frac{\sum_{i=1}^{n}(O_{i2})(p_{i1})}{(I_{ij2})(p_{ij1})} = \frac{\text{Base period price weighted total, column 6}}{\text{Base period price weighted input elements, column 6}}$$

**Figure 5.5 Cost Revenue Ratio Formulas**

insights as to where leverage exists. If Columns 10 and 11 are rank ordered, the manager can then invoke Pareto's Principle and make productivity improvement decisions, in terms of cost reduction, on the higher priority input resources. From this example one can easily see that a manager's leverage is with fiberglass and, in particular, with fiberglass prices.

From Column 11 it can be observed that labor costs are now (in period 2 or current period) 2.61 percent of revenues, a decrease from 3.55 percent in period 1. Fiberglass costs are now 31.68 percent of revenues, an increase from 20 percent. And total costs are now 34.8 percent of revenues, up from 24.18 percent.

## *Columns 12 and 13*

Columns 12 and 13 are titled "Productivity Ratios." Column 12 reflects the output-to-input ratios for period 1, while column 13 reflects the output-to-input ratios for period 2. This is a relatively new edition to this model and exists only on certain versions of the software for this particular productivity measurement technique. The formulas for these two columns appear in Figure 5.5.

## *Columns 14–16*

Columns 14–16 (Table 5.6) are titled "Weighted Performance Indexes." Column 14 reflects price-weighted productivity indexes. Column 15 represents quantity-

**Table 5.6 LINPRIM Boat Company Example (VPI/VPC Version MFPMM): Columns 14–19**

| | WEIGHTED PERFORMANCE INDEXES | | | DOLLAR EFFECTS ON PROFITS | | |
|---|---|---|---|---|---|---|
| | (14) | (15) | (16) | (17) | (18) | (19) |
| | CHANGE IN | | | CHANGE | CHANGE | CHANGE |
| | PRODUC-TIVITY | PRICE RECVRY | PROFIT-ABILITY | IN PRODUC-TIVITY | IN PRICE RECOVERY | IN PROFIT ABILITY |
| BOAT A | | | | | | |
| BOAT B | | | | | | |
| TOTAL OUTPUTS | | | | | | |
| LABOR MANAGEMENT | 1.340 | 1.045 | 1.401 | 2065.45 | [illegible] | [illegible] |
| LABOR GLASS | 1.340 | [illegible] | 1.369 | 2065.4[illegible] | 461.6[illegible] | [illegible] |
| LABOR ASSEMBLY | 1.340 | 0.995 | 1.321 | 2168.7[illegible] | [illegible] | [illegible] |
| TOTAL LABOR | 1.340 | 1.017 | 1.362 | [illegible] | [illegible]4.54 | [illegible] |
| FIBERGLASS | [illegible] | 0.676 | [illegible] | [illegible] | [illegible] | [illegible] |
| WOOD | [illegible] | 1.150 | [illegible] | [illegible] | [illegible] | [illegible] |
| TOTAL MATERIALS | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| ELECTRICITY | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| NATURAL GAS | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| TOTAL ENERGY | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| TOTAL INPUT | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

weighted price recovery indexes. And Column 16 depicts profitability indexes. The formulas for these three columns appear in Figure 5.6. Note that there are no entries for the cells corresponding to the output row elements. This is because Columns 14–16 are now calculating output over input indexes, or changes in performance ratios, from period 1 to period 2. The essence of the MFPMM appears in Columns 12–19.

As discussed in Chapter 2, there are at least four generic types of productivity "measures": (1) partial factor, static ratio; (2) total factor, static ratio; (3) partial factor, dynamic index; and (4) total factor, dynamic index. Recall that a dynamic productivity index is essentially a productivity ratio at one period in time, say, period 2 (current period), over that same productivity ratio at a previous period in time, say, period 1 (base period). Columns 14–16 calculate and depict dynamic *performance* indexes. Column 14 calculates and depicts dynamic *productivity* indexes. Figure 5.7 conceptually depicts what the MFPMM is doing.

In Figure 5.7, formulas and development of static productivity ratios are depicted. We take a snapshot of the organizational system for a given period of time and place some or all of the outputs in the numerator and one, some, or all of the inputs in the denominator. For a decoupled, disaggregated system, such as the NPMM, we do not necessarily need to use indexed prices and costs as a common denominator. For an aggregated system, such as the MFPMM, indexed prices and costs are necessary.

*Column 14:*

$$\frac{\dfrac{\sum_{i=1}^{n}(O_{i2})(p_{i1})}{\sum_{i=1}^{n}(O_{i1})(p_{i1})}}{\dfrac{(Iij_2)(p_{i1})}{(Iij_1)(p_{i1})}} \qquad \frac{= \text{Column 7 for total outputs}}{= \text{Column 7 for each individual input}} \qquad \text{Productivity}$$

*Column 15:* Column 14/Column 12

or

$$\frac{\dfrac{\sum_{i=1}^{n}(O_{i2})(p_{i2})}{\sum_{i=1}^{n}(O_{i2})(p_{i1})}}{\dfrac{(Iij_2)(p_{i2})}{(Iij_2)(p_{i1})}} \qquad \frac{= \text{Column 8 for total outputs}}{= \text{Column 8 for each input}} \qquad \text{Price recovery}$$

*Column 16:*

$$\frac{\dfrac{\sum_{i=1}^{n}(O_{i2})(p_{i2})}{\sum_{i=1}^{n}(O_{i1})(p_{i1})}}{\dfrac{(Iij_2)(p_{i2})}{(Iij_1)(p_{i1})}} \qquad \frac{= \text{Column 9 for total outputs}}{= \text{Column 9 for each input}} \qquad \text{Profitability}$$

**Figure 5.6 Weighted Performance Indexes**

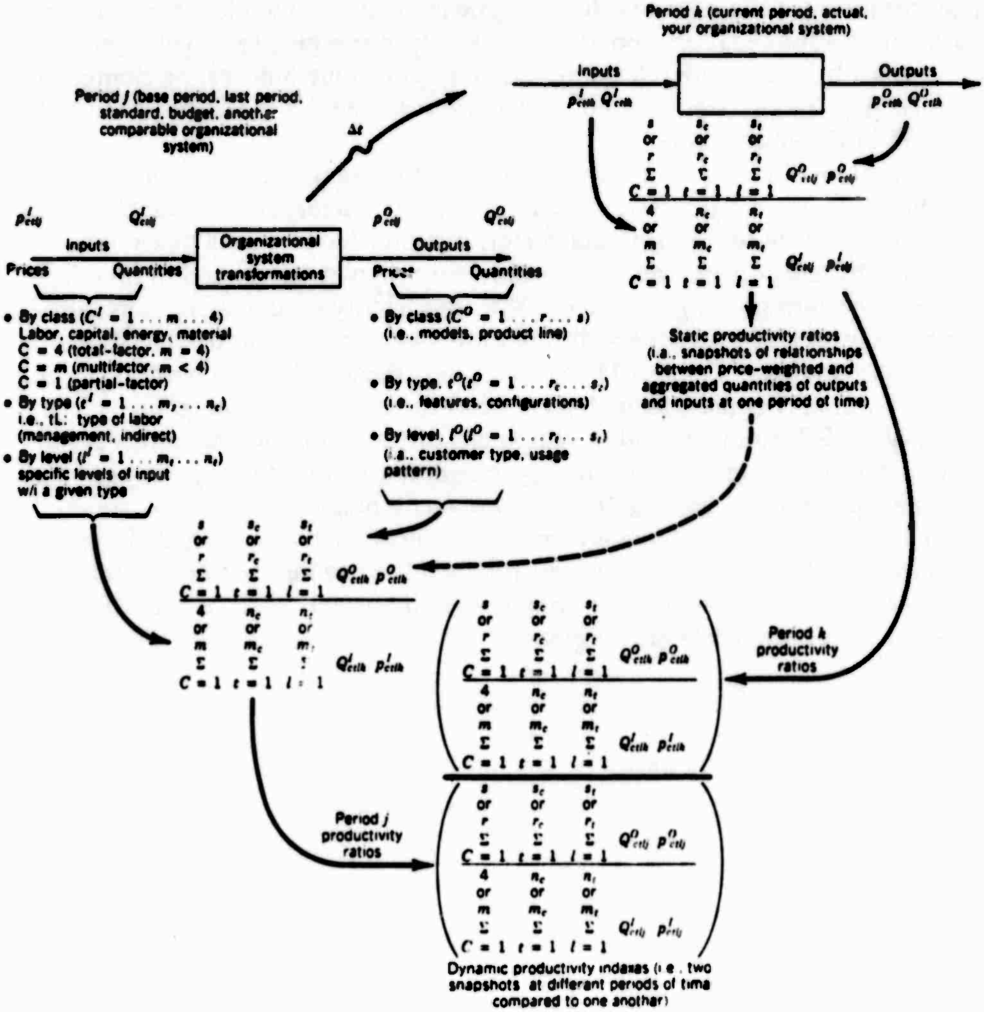



**Figure 5.7 Price-Weighted and Aggregated Multifactor Productivity Measurement Model**

Figure 5.7 also depicts formulas and development of dynamic productivity indexes. A snapshot of the organizational system's partial, multi-, and perhaps even total static productivity ratio is developed for period $k$ (period 2, current period). An equivalent snapshot of the organizational system's partial, multi-, or perhaps even total static productivity ratio is developed for period $j$ (period 1, base period, budget, standards, another comparable system, and so forth). The productivity ratios for period $k$ (period 2 or current period) are then divided by the productivity ratios for period $j$ (period 1 or base period). The resultant formulation is highlighted in Figure 5.7, and it is this calculation that is depicted in Column 14 of the MFPMM.

From Column 14 the following observations can be made:

1. Labor productivity increased by 34 percent.

$$\frac{\text{Column 7 for total outputs} = 1.2727}{\text{Column 7 for total inputs} = .95} = 1.34$$

(Note that Column 7 is the price-weighted changes in quantities for outputs and inputs. As an exercise, see question 13 at the end of this chapter to convince yourself that

$$\frac{O}{I} = \frac{Q_2^O/Q_1^O}{Q_2^I/Q_1^I} = \frac{Q_2^O/Q_2^I}{Q_1^O/Q_1^I}$$

This tells us that price-weighted change in outputs from period 1 to period 2 went up 27.27 percent while labor input went down 5 percent creating a corresponding gain in productivity of 34 percent.

2. Materials productivity decreased 7 percent.

$$\frac{\text{Column 7 for total outputs} = 1.2727}{\text{Column 7 for total materials} = 1.363} = 0.93$$

3. Total inputs productivity declined by 2 percent. Again, total price-weighted and indexed outputs from this company increased by 27.27 percent, while total price-weighted and indexed input quantities increased by 29.9 percent. Hence, 1.2727/1.299 = 0.98 and the calculated 2 percent decline in productivity for all inputs measured in this model formulation.

Column 15 depicts rates of change for quantity-weighted and indexed prices over costs. It reflects rate of price increases in relation to the rate of cost increases. In a sense it reflects the degree to which the organizational system was able to increase its price in relation to elemental input costs. It is simply termed price recovery.

From Column 15 it can be observed that

1. Price recovery for management labor was up 5 percent.

$$\frac{\text{Column 8 for total outputs} = 1.15}{\text{Column 8 for management labor} = 1.10} = 1.045$$

This indicates that the organization was able to raise prices approximately 5 percent faster than management unit prices (costs) increased.

2. Price for fiberglass increased approximately 32 percent faster than management was able to raise the prices of boats.

$$\frac{\text{Column 8 for total outputs} = 1.15}{\text{Column 8 for fiberglass input} = 1.7} = 0.676$$

3. On the whole, price recovery fell off by 29 percent.

$$\frac{\text{Column 8 for total outputs} = 1.15}{\text{Column 8 for total inputs} = 1.622} = 0.71$$

Changes in output prices were 71 percent of the changes in input costs. The company was not able or did not (for whatever reason) raise prices fast enough to compensate for increases in costs. (Note: Fiberglass price under-recovery was the major source of the relatively poor price recovery ratio of .71.)

Column 16 indicates profitability indexes, which reflect rates of change for simultaneous changes in price and quantity. The simplest way to think about Column 16 is that it is revenues/costs (a measure of profitability) for period 2 divided by revenues/costs for period 1. Hence, Column 16 is in reality a profitability index.

From Column 16 it can be seen that labor contributed to a 36 percent increase in profitability from period 1 to period 2. That is, revenues went up 46.36 percent from period 1 to period 2 (Column 9 for total outputs), while total labor costs increased by 7.46 percent (Column 9 for total labor) creating a 36 percent (1.4636/1.0746 = 1.3619) labor relative increase in profitability from period 1 to period 2. Materials created a period 1 to period 2 relative drain on profitability of 36 percent. Revenues changed at a rate of 46.36 percent, while material costs increased at a rate of 129.84 percent. Note that most of this drain on potential profits, which could have been achieved from the 46.36 percent increase in revenues, was caused by the 131.82 percent increase in fiberglass costs (both increased unit cost and increased quantity usage).

Overall, Column 16 depicts a 31 percent decline in potential profitability. This company was 31 percent less profitable in period 2 than it was in period 1. The company may well have made profits, but it could have made 31 percent more profits had certain price under-recovery situations not occurred. It should by now be clear that a number in Column 14, 15, or 16 that is greater than 1.00 reflects a positive change and a number less than 1.00 reflects a negative change. Therefore, our overall evaluation of this particular organization's productivity, price recovery, and profitability performance on a period 1 to period 2 basis is not favorable. In particular, management or an analyst could be concerned about fiberglass cost recovery.

## *Columns 17–19*

Columns 17–19 reflect the dollar equivalence of corresponding cells in Columns 14–16. In other words, these columns indicate what impact an increase in productivity (Column 17) or price recovery (Column 18) has on profits. The total impact on profits from productivity and price recovery is indicated in Column 19. The formulas for these columns appear in Figure 5.8. From these columns we see the following.

1. *Column 17:* Management labor productivity contributed \$2065.45 to profits from period 1 to period 2.

$$(1.2727 - .95)\$6400 = \$2065$$

*Column 18:* The model does not directly calculate Column 18, effect of price recovery on profits. Column 18 values are calculated by subtracting Column 17 values from Column 19 values. In other words, Column 17 + Column 18 = Column 19.

*Column 19:* Management labor contributed positively to profits between period 1 and period 2 to the tune of \$2679. About \$2065 came from productivity gains and \$613 came from price recovery gains.

$$(1.4636 - 1.045)\$6400 = \$2679$$

*Column 17:*

$$\begin{bmatrix} (Iij_1)(P_{i1}) \\ \text{or} \\ \text{Column 3} \\ \text{for each} \\ \text{corresponding} \\ \text{input} \end{bmatrix} \left[ \left( \frac{\sum_{i=1}^{n} (Q_{i2})(p_{i1})}{\sum_{i=1}^{n} (Q_{i1})(p_{i1})} \text{ or } \begin{matrix} \text{Column 7} \\ \text{for total} \\ \text{outputs} \end{matrix} \right) - \left( \frac{(Iij_2)(p_{j1})}{(Iij_1)(p_{j1})} \text{ or } \begin{matrix} \text{Column 7} \\ \text{for each} \\ \text{input} \end{matrix} \right) \right]$$

*Column 18:* Column 19 − Column 17

*Column 19:*

$$\begin{bmatrix} (Iij_1)(p_{j1}) \\ \text{or} \\ \text{Column 3} \\ \text{for each} \\ \text{corresponding} \\ \text{input} \end{bmatrix} \left[ \left( \frac{\sum_{i=1}^{n} (Q_{i2})(p_{i2})}{\sum_{i=1}^{n} (Q_{i1})(p_{i1})} \text{ or } \begin{matrix} \text{Column 9} \\ \text{for total} \\ \text{outputs} \end{matrix} \right) - \left( \frac{(Iij_2)(p_{j2})}{(Iij_1)(p_{j1})} \text{ or } \begin{matrix} \text{Column 9} \\ \text{for each} \\ \text{input} \end{matrix} \right) \right]$$

**Figure 5.8 Weighted Performance Indexes, Individual Effects on Profits**

2. *Total materials Column 19:* Low productivity in materials utilization created a drain on profits from period 1 to period 2 of −\$10,136. About \$10,000 of this decline came from low fiberglass productivity alone.

$$(1.2727 - 1.363)\$112{,}250 = -\$10{,}136$$

*Total materials Column 19:* Very poor price recovery on fiberglass and low productivity created a −\$93,706 drain on profits for this company from period 1 to period 2.

$$(1.4636 - 2.2984)\$112{,}250 = -\$93{,}706$$

This reflects the drain on profits caused by an inability to recover rising costs from period 1 to period 2. As one can see, the biggest source of lowered profits from period 1 to period 2 is this category.

3. Overall, this boat manufacturing company was \$85,536 less profitable in period 2 than in period 1 had nothing changed in the company. About \$82,047 of this decline in profits is attributable to relatively poor price recovery. And, as indicated, very poor fiberglass price recovery is the major source of this total decline in profits.

This completes the description and example for the MFPMM. There are obviously many fine details, application and implementation issues, and refinements that could be discussed. Some of these points will be dealt with in this section. However, at this point, the reader should have a good grasp of the basic character of the model. It is a relatively simple model and yet it has tremendous potential as an integrative decision support system. There are applications at the end of this chapter that can be utilized to develop more skill and a deeper understanding of how to interpret program output. Those desiring to purchase the model software can experiment with the model quite painlessly. You might even wish to collect data from a specific example of your own and run the program. Like any decision support system, the model itself is a critical but rather minor component of an application. Integrating the model into an existing control system, collecting the data, getting management to accept and feel comfortable with the system, and selling the system based on benefit-to-cost projects are all activities that actually play a more critical role in successful implementation of such a system.

In an attempt to improve the decision support capabilities of the model, staff at the Oklahoma Productivity Center and now at the Virginia Productivity Center have developed a simple simulation routine to allow management to project the impact of productivity improvement interventions on profits. This development is the focus of the discussion in the next section.

4. LTV Integrated Approach

LTV Aerospace and Defense Company's Vought Aero Products Division (VAPD) has developed a comprehensive productivity improvement program that operates at different levels of business activity, from total corporation down through departmental levels. The program assimilates productivity improvement themes into the routine operations of the company by focusing attention on the following:

1. Strategic Plan: establish competitive productivity targets
2. Development Plan: select projects with employee participation
3. Budgets: synchronize budgetary controls with productivity targets
4. Operations: use measurements to monitor performance
5. Profits: apply Department of Defense (DOD) incentives to generate savings and profits

Competitive Targets

Companies can establish competitive targets for productivity improvement with the aid of a mathematical relationship that exists between profitability, productivity and price-recovery:

$$\boxed{\frac{\text{COST}}{\text{SALES}}} = \boxed{\frac{\text{RESOURCE QUANTITY}}{\text{PRODUCT QUANTITY}}} \times \boxed{\frac{\text{RESOURCE PRICE}}{\text{PRODUCT PRICE}}} \quad . . .(1)$$

$$\boxed{\text{PROFITABILITY}} = \boxed{\text{PRODUCTIVITY}} \times \boxed{\text{PRICE-RECOVERY}}$$

Here profitability is the ratio of "cost" to "sales". Productivity is the "input:output" relation of resources consumed and products or services produced. Price-recovery deals with relative inflation, or the extent to which increases in the cost of resources are recovered through product price changes. The mathematical relationship remains just as true for a whole industry as for individual corporations.

Since forecasts of industry sales, profits and inflation are commercially available, it is possible to calculate an industry's anticipated productivity improvement. Companies can, therefore, compare their own potential for improvement with the industry and select a competitive productivity target which will produce, over time, a strategic advantage in pricing (Figure 1).

## Productivity Projects

Productivity is not a new imperative. It has been relevant since the start of the industrial revolution. In the early years of industrialization, production methods were labor intensive. Therefore, the effort to improve operations was focussed on "production efficiency". This started a tradition which narrowly associated productivity with production labor. That single-minded attention to production is undergoing a change. Improvements in manufacturing technology have modified the cost structure of products. The cost drivers have shifted from production to support and overhead areas (Figure 2). In the context of total company modernization, therefore, a local focus on manufacturing is insufficient. Manufacturing modernization, by itself, cannot fulfill the goal of competitive improvements in productivity. Productivity goals must, therefore, be broadened. To appreciate the diverse applications of new projects for productivity improvement, consider the list in Table 1. The cited projects are a small selection from the wide range of modernization initiatives being taken at Vought Aero Products Division. They nevertheless demonstrate that it is feasible to simultaneously address all facets of company costs.

Total modernization of a company is a substantial task and it is helpful to accomplish it in a cooperative effort by all employees. VAPD utilizes the Nominal Group Technique [1,2] to conduct employee participation meetings and generate ideas for productivity improvement. Employees vote on their ideas

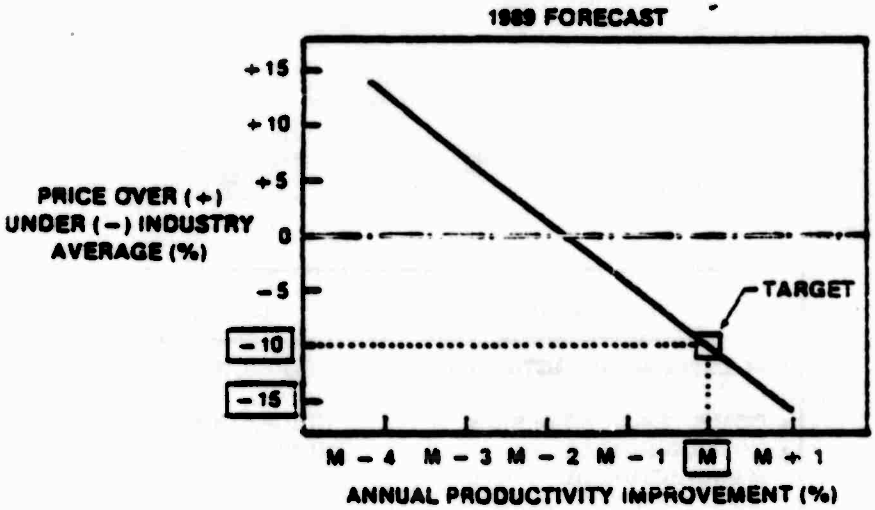



FIGURE 1 COMPETITIVE PRICING BENEFITS

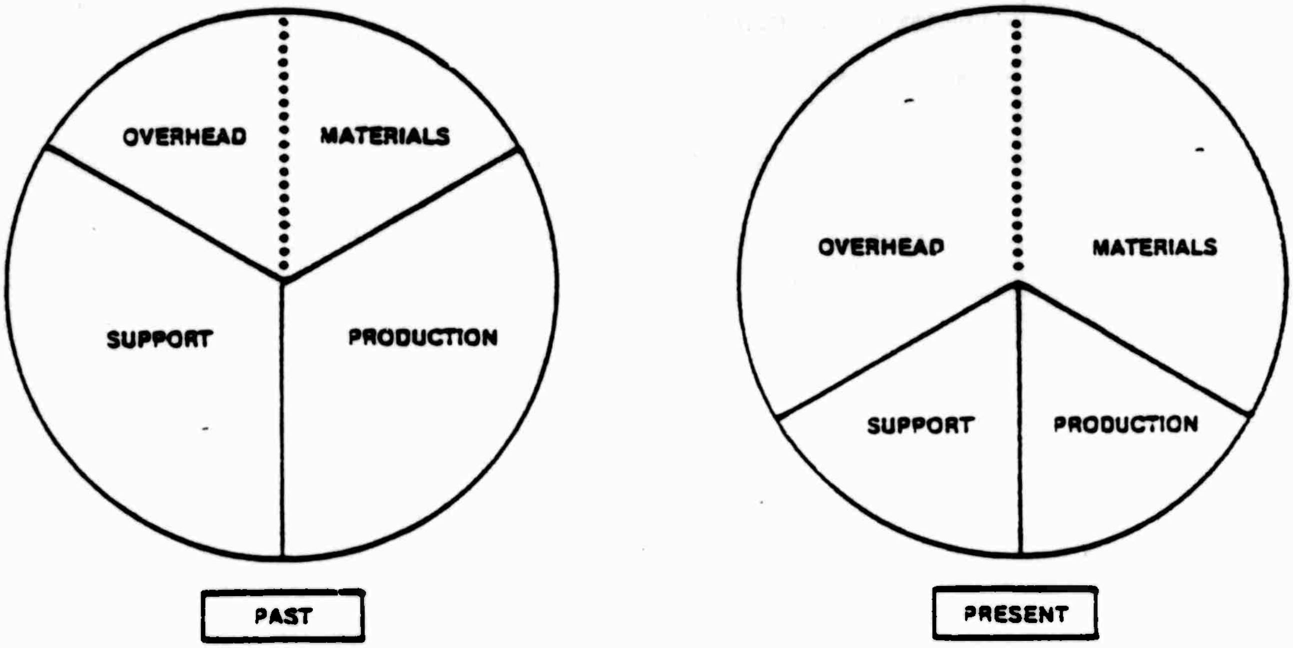



FIGURE 2 CHANGE IN COST DRIVERS

TABLE 1 PRODUCTIVITY PROJECTS

| PROGRAM | FOCUS |
|---|---|
| • FLEXIBLE MANUFACTURING | PRODUCTION |
| • COMPUTER-AIDED DESIGN<br>• COMPUTER-AIDED MANUFACTURING | ENGINEERING SUPPORT |
| • INVENTORY REDUCTION/JUST-IN-TIME | OVERHEAD |
| • AUTOMATED PROCUREMENT | MATERIALS |
| • OFFICE OF THE FUTURE | WHITE COLLAR |
| • EMPLOYEE BADGE BASED AUTOMATION (ENTRY, ATTENDANCE, PAYROLL) | SECURITY AND FINANCE |
| • ENERGY MANAGEMENT SYSTEMS | ENERGY |
| • ARTIFICIAL INTELLIGENCE BASED BIDS AND PROPOSALS | SALES |
| • AUTOMATED WAREHOUSING SYSTEMS | WAREHOUSING |
| • EMPLOYEE MOTIVATION AND GAINSHARING | GENERAL |

to create a ranked list. Higher ranked ideas are packaged into projects and cost analyzed for review by departmental management (Table 2). By this process, each department develops a long-range productivity improvement program for implementation in its area.

Budgets and Controls

Competitive productivity improvement is a demanding objective. For a company incurring $1 billion in costs of goods sold, a 5% productivity improvement target implies annual cost reduction of about $50 million. Such goals require budgetary discipline. If an expansive budget is approved at the start of the year, it cannot yield cost efficiencies by year-end. The environment for cost improvement must be built into the budget, ahead of time.

Equation (1) suggests that productivity improvement targets and operating costs, or budgets, are mathematically related. Sales, costs and profits are all influenced by productivity. However, the scope of that influence is masked by inflation. If the effects of inflation are removed, by comparing sales and costs in "constant dollars", changes in productivity become apparent (Figure 3). VAPD uses these relationships to monitor cost and productivity trends at the company level. As shown in Figure 4, costs or budgets are expressed as a percentage of "output". Output is defined as "sales plus change in inventory". Management of this cost index is considered vital to the control of the total company budget.

Department level budgets can be derived from the total company budget by following two principles. First, the principle of limited resource states that total resources allocated to the departments must equal those allocated to the company. Within that premise, productivity targets do not have to be uniform in all departments. However, below nominal assignment of improvement targets to certain departments have to be compensated by above nominal

TABLE 2 PROJECT SELECTION AND ANALYSIS

## HUMAN RESOURCES

### EXAMPLE OF EMPLOYEE PARTICIPATION (NGT) RESULTS FOR ONE PROJECT

| RANKING | | PROJECT | VOTES | SCORE |
|---|---|---|---|---|
| [illegible] | [illegible] | | | |
| 11 | 2 | Employee Badge Based Automation:<br>• Closed Circuit TV Check at Entry and Exit<br>• Automated Attendance – Eliminate Time Cards<br>• Automated Vehicle Parking Assignment<br>• Automated Guard Assignment Schedules | 7 | 31 |
| Assigned to IMOD | | | | |

### COST ANALYSIS FOR PROJECT: EMPLOYEE BADGE BASED AUTOMATION

| PROJECT | POTENTIAL IMPROVEMENT | | | | IMPLEMENTATION COSTS $M | | FOCUS |
|---|---|---|---|---|---|---|---|
| | [illegible] | | [illegible] | | | | |
| | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| • Employee Badge Based Automation | 96<br>18<br>4000<br>– | 38<br>7<br>1400<br>– | 15.0<br>6.0<br>0.8<br>$ 2.5M/YR | 5.7<br>0.7<br>11.2<br>21.0<br>------<br>$ 4.825M | 4.2 | 2.0 | • Security<br>• Mail Room<br>• General<br>• Interest |

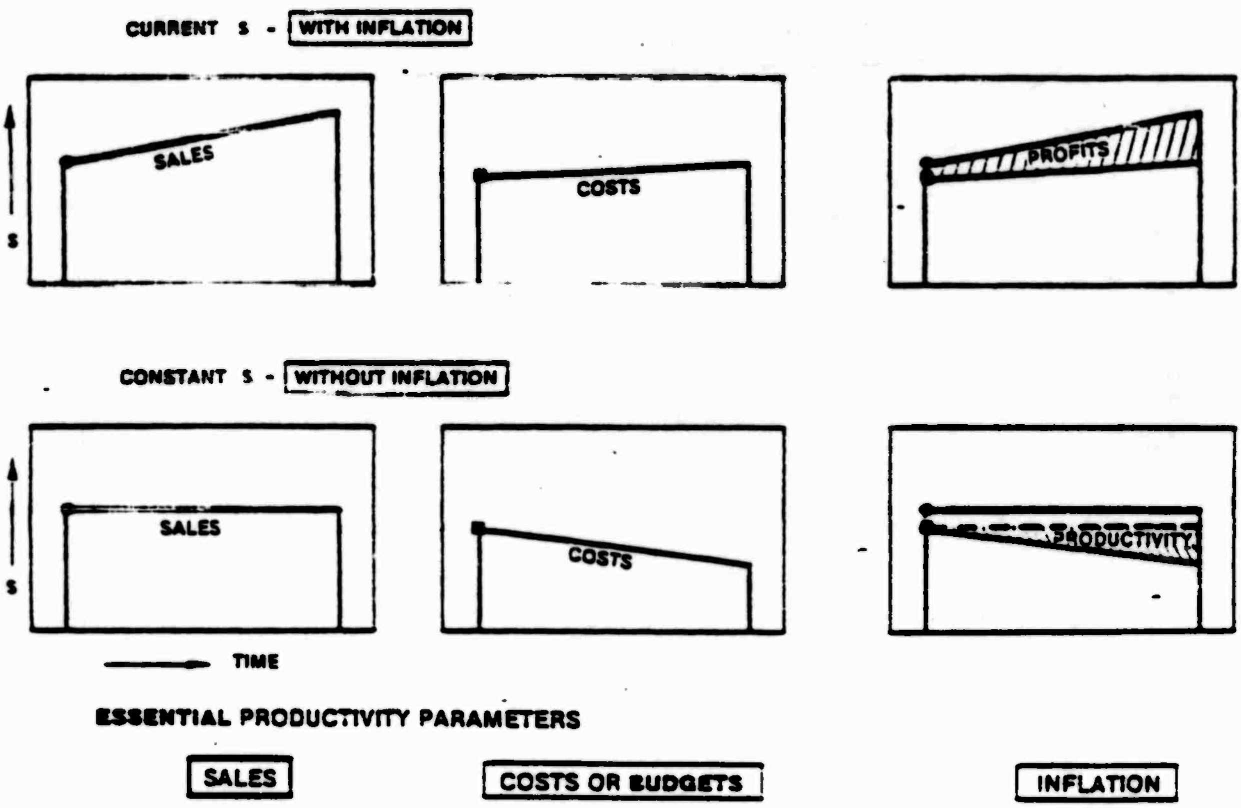



FIGURE 3 MODEL OF PRODUCTIVITY

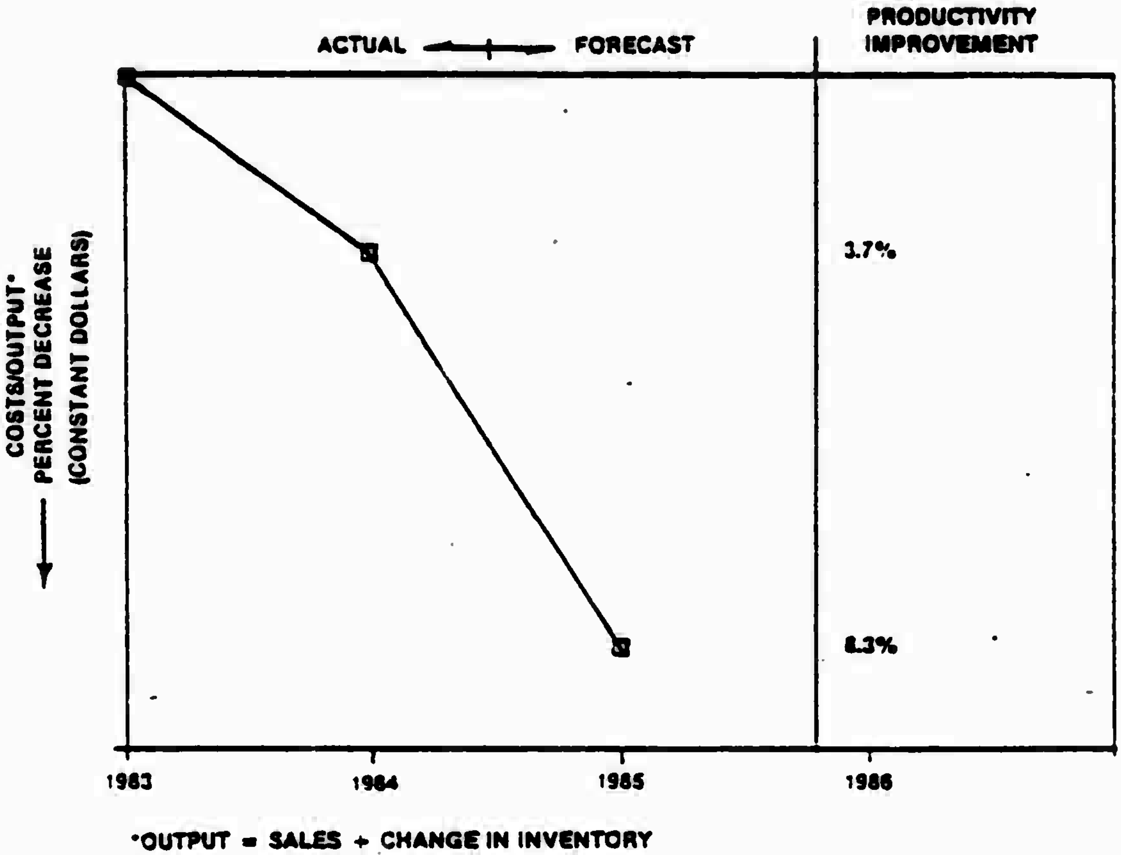



FIGURE 4 TREND OF DECLINING COSTS

assignment to others. Second is the principle of shared targets which states that the responsibility for improving productivity for a resource can be shared by two or more departments. For example, capital and energy resources are commonly shared. By making a fair, pre-negotiated allocation of the actual performance, favorable or otherwise, amongst sharing departments, team play can be encouraged.

## Performance Measurement

Companies have used performance measurements in the production area for many years. However, production costs and their proportional ratio to total company costs have progressively declined. The resulting modification of the cost structure has created the need to address both production and non-production costs. VAPD has, therefore, expanded the application of measurements to its non-production areas.

The traditional method of measuring performance in the production area involves the use of work standards. Such standards are developed by a cost-intensive, analytical, multi-step method shown in Figure 5 A. While effective in the production area, this technique is costly, specialized, and cannot be universally applied to overhead and support functions. Therefore, VAPD uses other simpler and less cost-intensive methods for application in non-production areas. Techniques such as "input:output" or "activity:indicator" ratios [3], as shown in Figure 5 B are utilized to provide reliable measurement at a lower cost.

Figures 6 and 7 illustrate the performance charts used at the unit level and the department level. The charts feature sections denoted as "PERFORMANCE" and "RATING". The PERFORMANCE shown pertains to individual measurement. Since measurements are often diverse and cannot be mathematically added, the RATING category is used to convert all performances

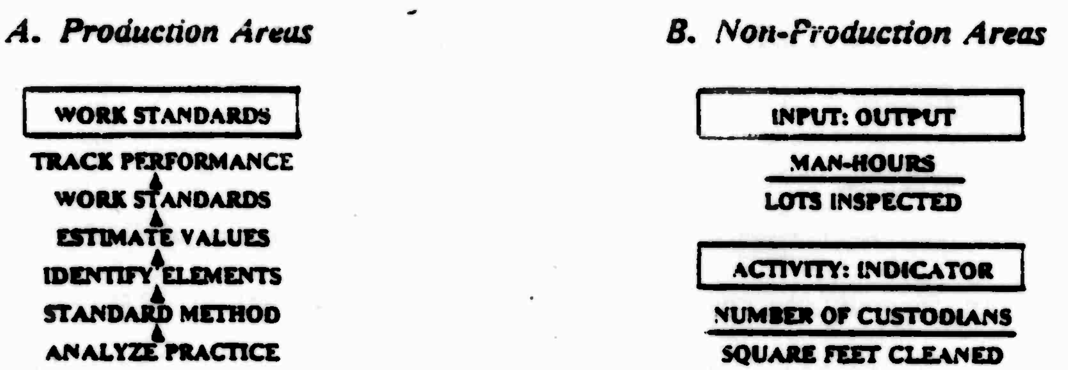



FIGURE 5 MEASUREMENT TECHNIQUES

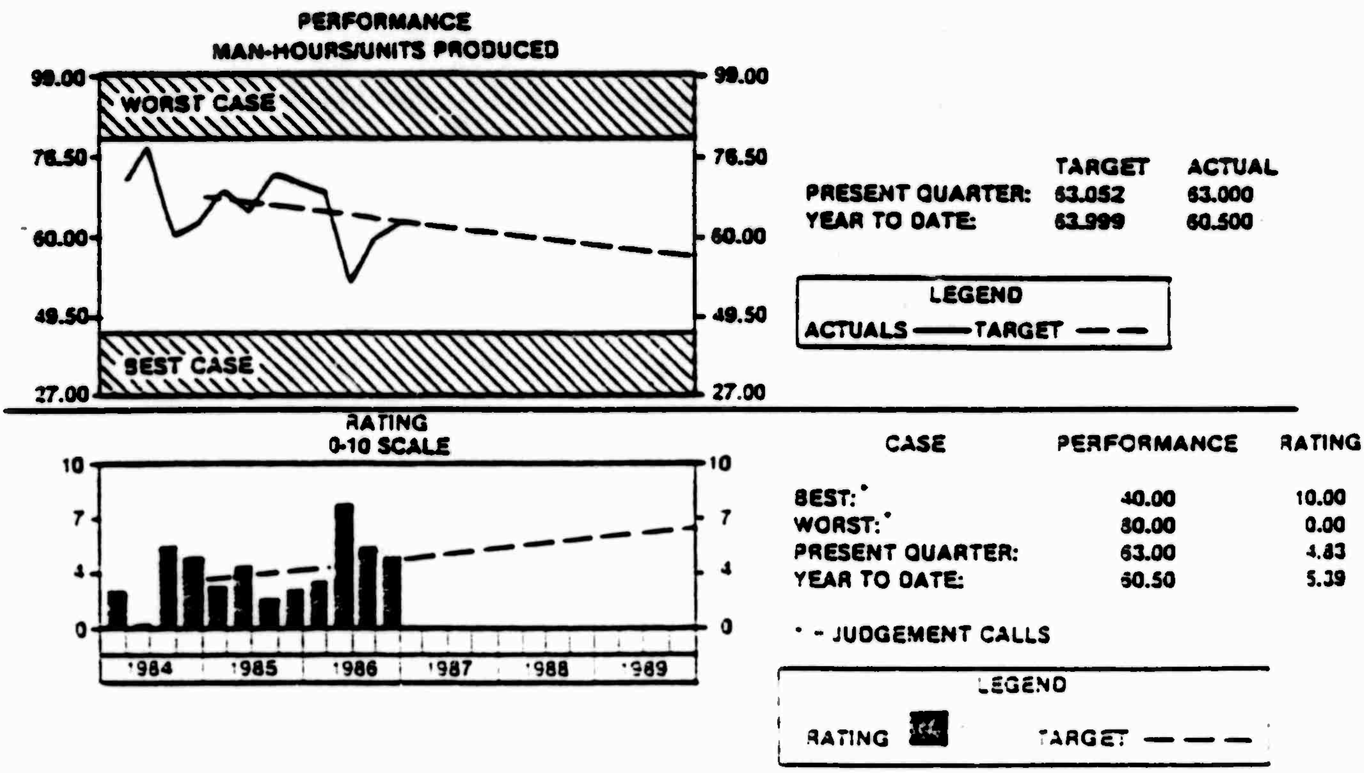



FIGURE 6 UNIT LEVEL PERFORMANCE

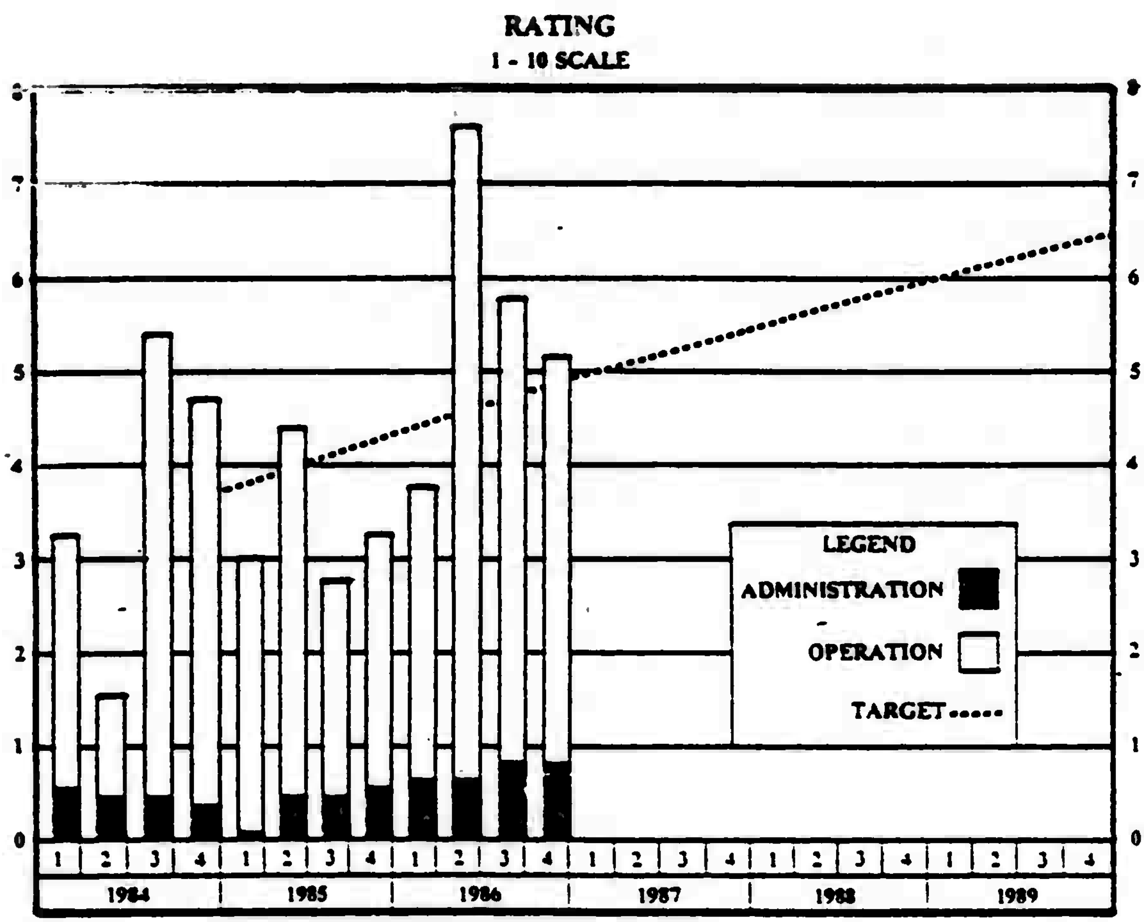



FIGURE 7 DEPARTMENT LEVEL PERFORMANCE

to a common scale of 0 ("worst case") to 10 ("best case"). Such a conversion allows comparison between diverse measurements, as well as calculation of a department's total performance. In this manner, measurements are used to monitor performance improvement and provide cost trends for future bids and proposals.

<u>Savings</u>

Two problems have been cited most frequently as inhibiting productivity improvement and modernization in defense contracts:

- Program uncertainties
- A cost-oriented profit policy

In the first instance, risks are introduced which hinder investment amortization and inhibit long-term planning. Due to the second problem, a contractor may actually see profits reduced as a result of efforts to improve productivity and reduce costs. DOD has introduced an Industrial Modernization Incentive Program (IMIP) as a tool to overcome these impediments[4]. The central idea in IMIP is to negotiate a business arrangement with benefits to both parties:

- Contractor - investment protection
  - shared savings
- Customer - reduced acquisition costs

Investment protection to the contractor overcomes risk associated with program instability. Shared savings on current and future programs increase the contractor's rate of returns and profits.

The IMIP program is especially attractive because its concept of shared savings can be applied to both manufacturing and non-manufacturing modernization. Since VAPD has a broad based program for productivity improvement initiatives in all departments, it has developed a uniform approach to IMIP which is based on the assumption that the contractor's shared savings would come from improvements in performance. Improvements are measured by comparing a pre-determined "baseline" performance with "actual" performances in the future (Figure 8). Readily available measurements are used to monitor the performance of modernization projects (Table 3). Shared savings for any given year are calculated in three steps as shown in Table 4. Step 1 measures "improvement", step 2 calculates "savings" and step 3 "allocates" savings to multiple programs. It should be noted that the IMIP program allows DOD agencies to mutually agree and designate a lead buying office for each company where IMIP is to be pursued. That buying office becomes the IMIP focal point for the contractor to accommodate modernization projects that cut across multiple programs.

The productivity improvement program described above serves the special needs of VAPD. While some of its features may have wider application, it is not a magic formula for success. More important than the structure of any program is the degree to which the usage of productivity tools becomes natural to a company's daily operation. A program, at its best, becomes so pervasive as to be anonymous.

A more complete description of LTV's Integrated Approach is included as Appendix A.4 in this Volume I of the Final Report.

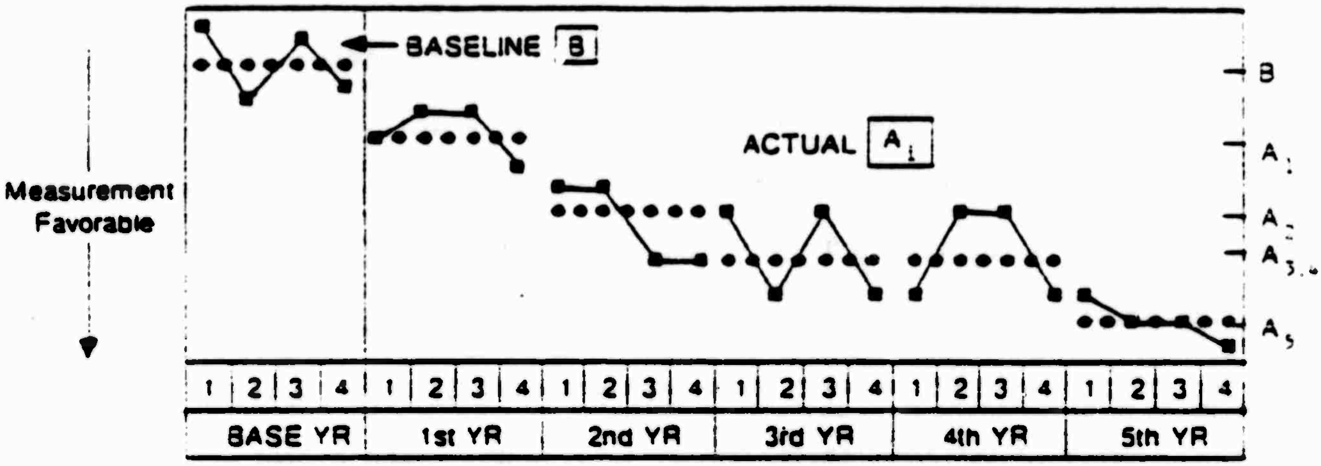



FIGURE 8 PERFORMANCE MEASUREMENT

TABLE 3 EXAMPLES OF MEASUREMENTS

| PROJECT | MEASUREMENT |
|---|---|
| OFFICE OF THE FUTURE | \$ TECHNICAL PUBLICATIONS & REPRODUCTION / \$ VAPD SALARIED LABOR COSTS |
| INVENTORY REDUCTION | \$ AVERAGE WIP INVENTORY / \$ ANNUAL SALES + CHANGE IN WIP |
| FLEXIBLE MANUFACTURING | \$ COST OF SALES (AFFECTED PARTS) / \$ AS-IS STANDARD HOURS |

TABLE 4 CALCULATION OF SHARED SAVINGS

Step 1 - Improvement:

| BASELINE PERFORMANCE | PERFORMANCE IN YEAR (i) | IMPROVEMENT (%) |
|---|---|---|
| B | Ai | (B - Ai) % |

Step 2 - Savings:

| INCREMENTAL SAVINGS PER PERCENT IMPROVEMENT ($/%) | TOTAL SAVINGS ($) | CONTRACTOR'S SHARE (%) | PSR ($) |
|---|---|---|---|
| Ii | Si = Ii (B-Ai) | C% | P = C · Si |

Step 3 - Allocation:

| Program | L | M | N | Total |
|---|---|---|---|---|
| Sales ± Change in WIP (%) | 20 | 50 | 30 | 100 |
| Allocated PSR ($) | 0.2P | 0.5P | 0.3P | P |

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2. Sink, D. S. "Productivity Action Teams: An Alternative Involvement Strategy to Quality Circles," Annual Industrial Engineering Conference Proceedings. Atlanta, Georgia: Institute of Industrial Engineers, 1981.

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## 1. APPLICATION OF CDEF

The CDEF methodology is intended to complement a company's strategic operational planning process. The application of CDEF assumes that competitive market objectives have been established and disseminated to those responsible for production planning. Ultimately, CDEF will be used to facilitate a top-down planning effort and avoid "solutions looking for a problem", that may result in a company implementing islands of technology.

Ideally, CDEF is applied first at the macro (facility/company) level to identify areas of low performance, the current or direct cost of manufacturing, and to isolate obvious areas of concern. Application at the micro level would follow as improvement projects are identified and implemented.

It has been our experience, however, that many companies identify improvement projects without doing the up-front analysis that CDEF advocates. In these cases, backtracking has been required and frequently projects which "appeared" to be beneficial have in actuality had significant offsetting costs.

Once a top-down analysis using CDEF has been undertaken, a pattern for performance and cost improvement project identification, justification and selection can be established.

Admittedly, the CDEF process is not a small endeavor. However, the costs of selecting inappropriate improvement projects using outdated techniques can far outweigh the costs associated with utilizing the CDEF methodology and selecting projects that reflect true cost and performance improvements.

2. DCF/SSA

The DCF/SSA model application is appropriate only after certain requirements have been satisfied. A top-down structured factory wide analysis must be performed. Structured cost benefits analysis (CBA) methods must be utilized in compliance with cost accounting standards (CAS), Contractor disclosure statements, and negotiated rates and factors.

At this point, the DCF rate of return analysis may occur by calculating the appropriate shared savings incentive dollar value necessary to realize an established percentage rate of return.

The IMIP approach to analyzing the applicability of modernization projects is to model the most effective, efficient, reliable and productive means to guide the product through its required manufacturing processes. The following objectives should be given major consideration:

- Minimize the quantity of direct labor
- Minimize material handling
- Minimize the product manufacturing cycle
- Maximize process yield (quality)
- Maximize the integration of systems with the latest in manufacturing methods

A top-down structured methodology needs to be developed for each of the proposed modernization projects based on individual evaluations and compared to the overall contractor business and resource requirements (figure 2-1). Overall program risk is based on theoretical feasibility, conciseness of program definition, performance requirements, reliability/maintainability/availability, schedule, and costs.

Figure 2-2 reflects the typical cycle for the development of a modernization project and provides an overview for establishing phased requirements for successful and acceptable implementation.

Following the top-down analysis approach and identification of high cost repair/manufacturing areas, an analysis of advanced technologies, equipment, quality, and management information systems is conducted to determine the financial desirability of active implementation of the identified improvements. Figure 2-3 outlines the analysis methodology which identifies the sources of supportive data and provides for consistent organization of individual projects.

The contractor's costing rates are typically utilized to recover investment dollars applicable to the particular business unit in accordance with that business unit's cost accounting standards disclosure statement. In most cases, the use of composite rates will cause levels of variation from actual realized costs to the composite costs accumulated in the accounting system. This costing rate variance has a significant impact on the rate of return reported and needs an impact analysis review similar to that conducted for alternative technical scenarios. This necessitates the reevaluation of the cost rates structure to insure effective evaluation of IMIP projects.

The ICAM Program was assigned the task of defining the structure and components of a computer integrated manufacturing system and implementing that system into a demonstration environment.

The primary analytical tools used during a project lifecycle are the ICAM Definition (IDEF) Methodologies. The IDEF Methodologies can be used to analyze current manufacturing operations, and propose changes in system design for future operations. In addition, the IDEF Methodologies can be used to assess benefits and risks associated with the implementation of new technology.

The $IDEF_0$ function model, in Figure 2-4, provides complete definition of the functions performed and function relationships of a system. This definition consists of the inputs, outputs, controls, and mechanisms associated with each functional element. The functions are linked by the inputs and outputs; the resource requirements are defined by the mechanisms; and, the effects of the controls imposed by management are taken into account.

The $IDEF_0$ function model does not necessarily, by design, correlate to a contractors accounting organization structure. Therefore, costs allocated to Function Model nodes, do not necessarily track to costing rates and factors used in pricing and/or cost accounting. A correlation needs to be accomplished to meet the requirements of quoting costs and/or savings in accordance with the contractors disclosure statement as required by Public Law 87-653.

There is more than one source of funds needed to invest in manufacturing improvement to achieve significant cost reduction, quality improvement and compressed manufacturing cycle time strategic objectives. Companies are utilizing capital, overhead, and independent research and development funds which are applied in the negotiated annual rates and factors as well as government funded development, eg Manufacturing Methods Technology (MMT), Tech Mod and/or product program directed funds as well as IMIP shared savings and/or enabling technology development.

The expense portion of company funded investment is included in the Discounted Cash flow analysis while government funded investment is considered zero expense to the contractor. The capital and associated installation/debug/test acceptance expense is depreciated over the life of the asset.

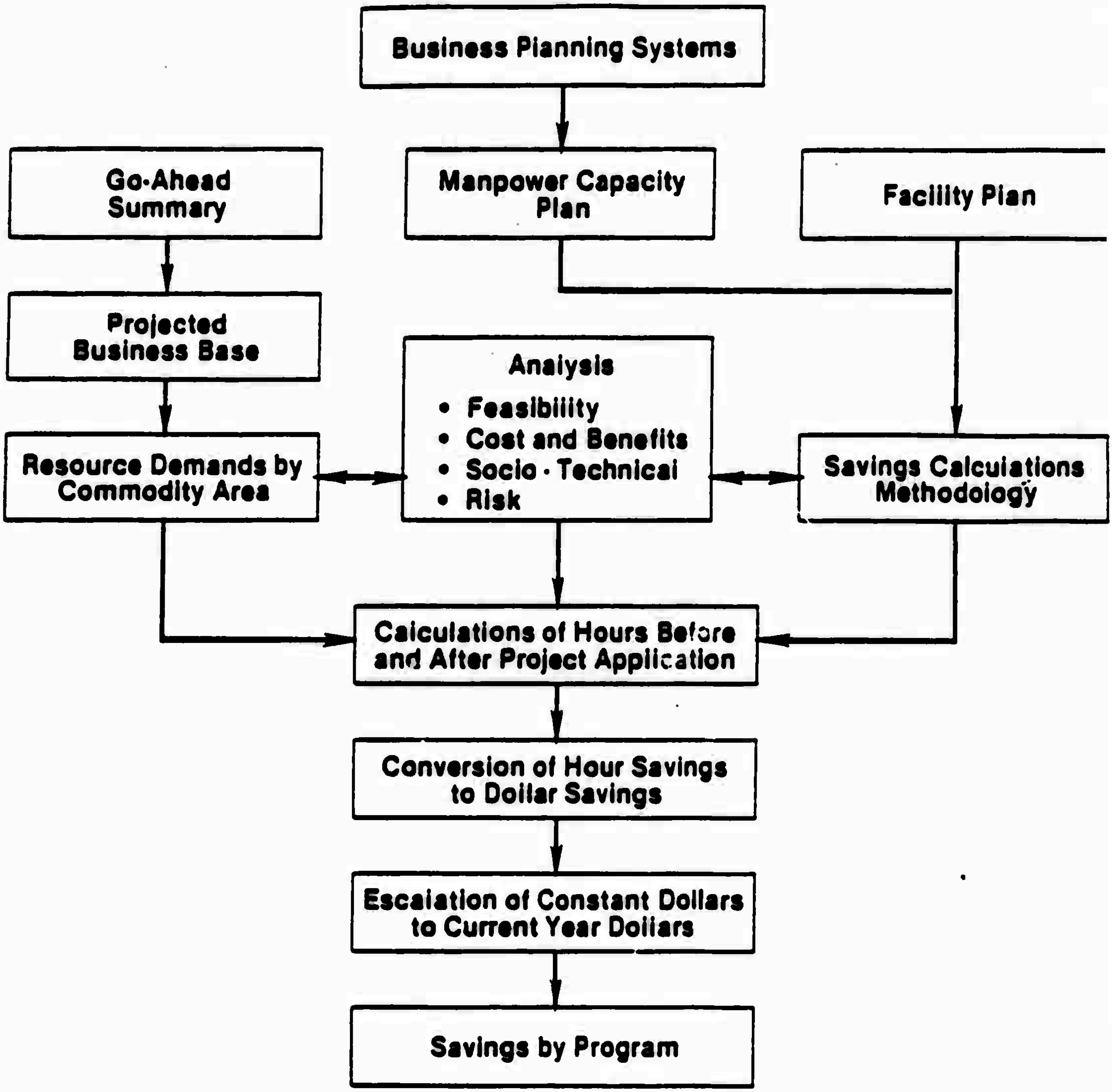



Figure 2-1. Technology Modernization Project Evaluation

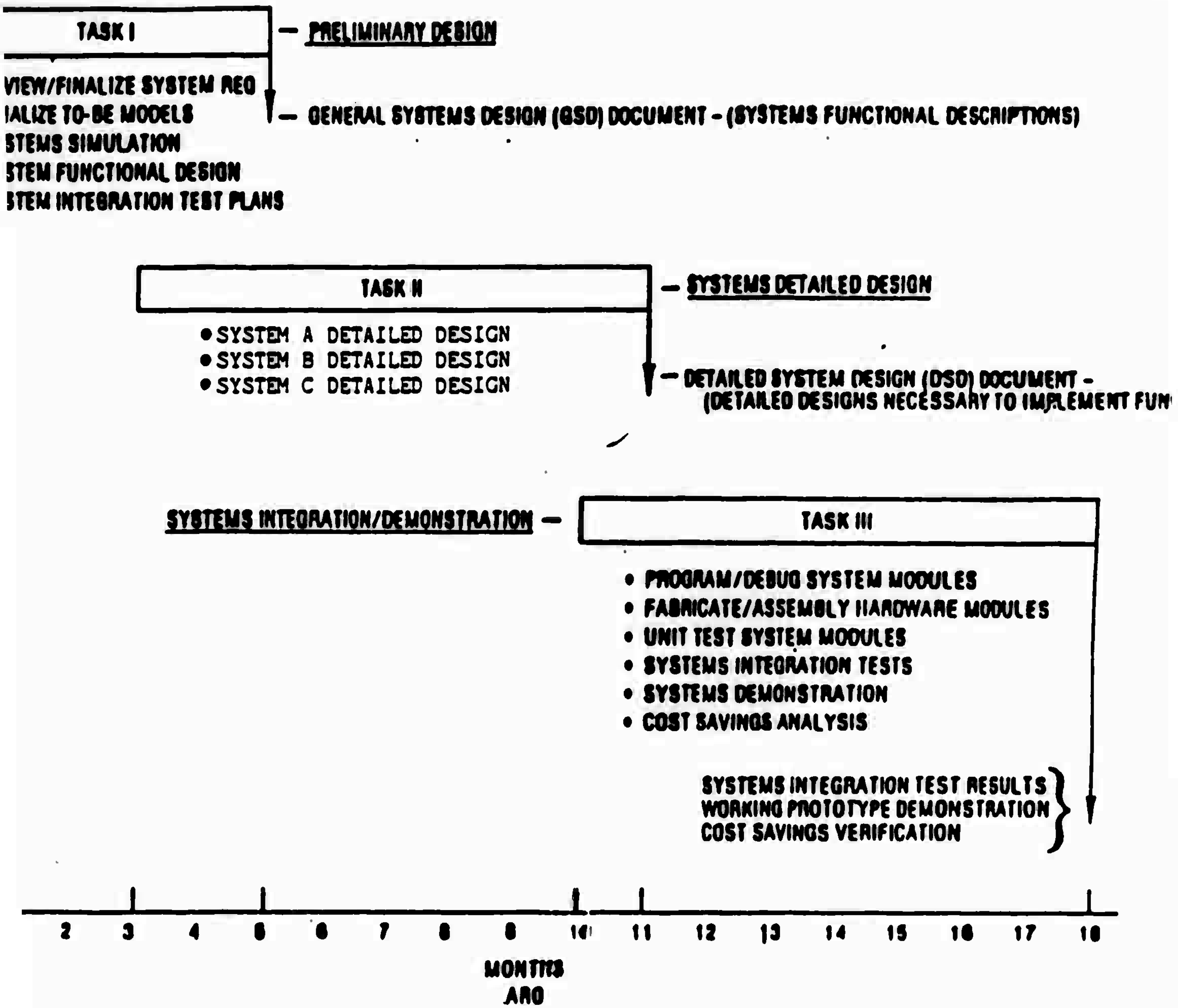



Figure 2-2. Tasks Schedule

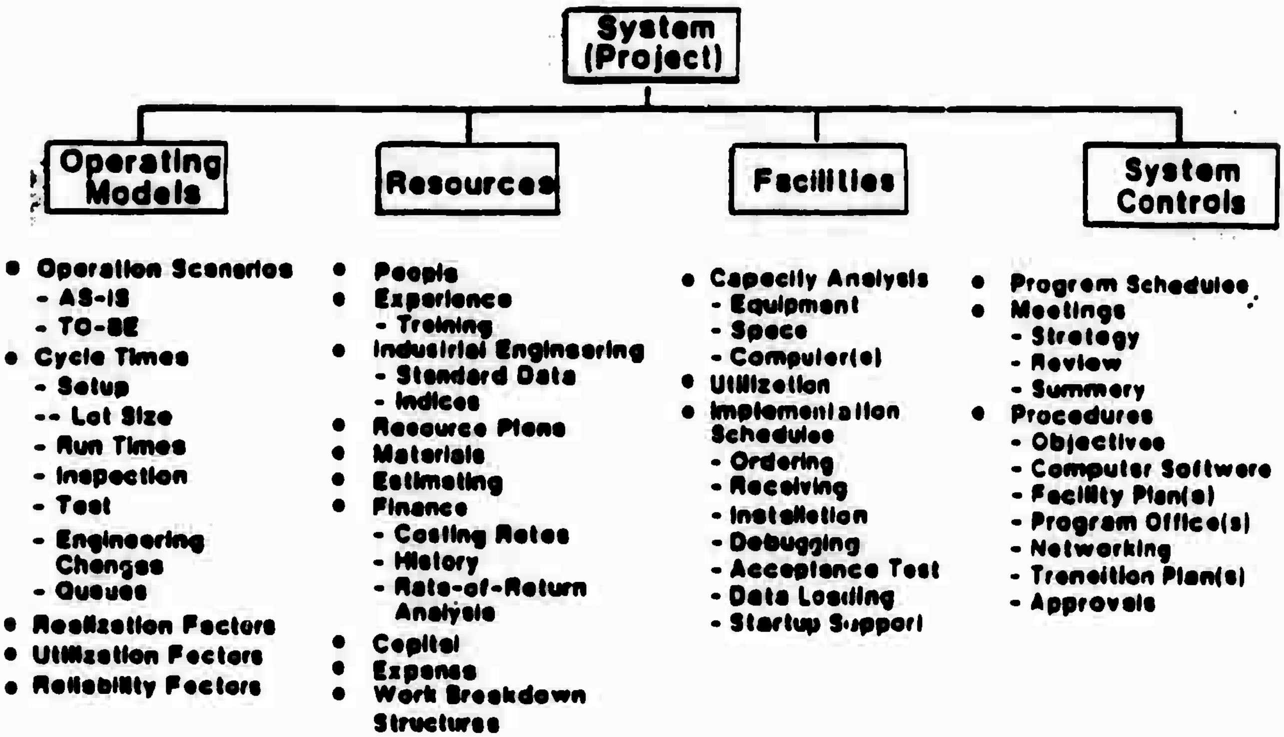



Figure 2-3. Cost/Benefits Analysis Methodology

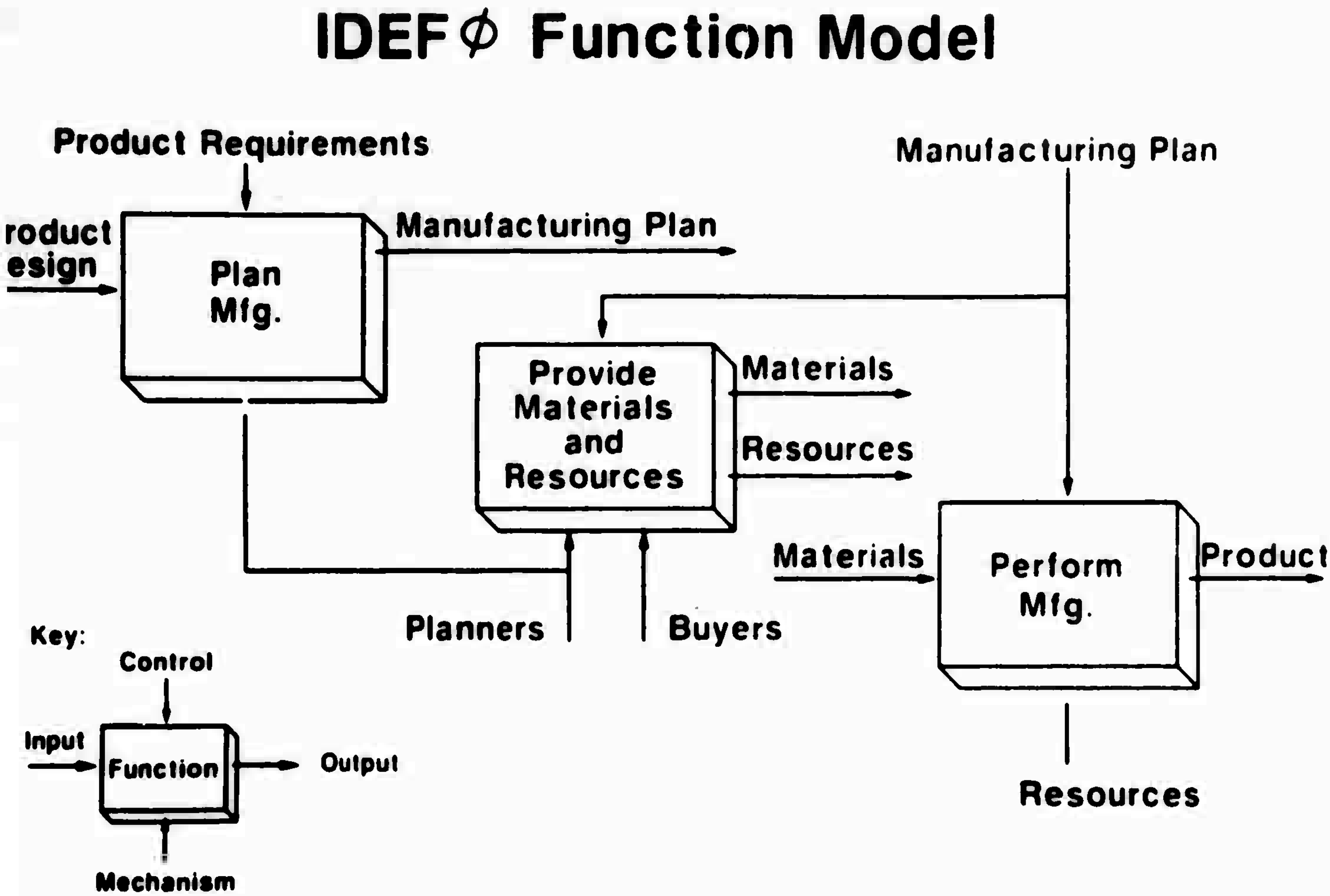



Figure 2-4. IDEFØ Function Model

## REQUIREMENTS

A). Business Base

A time-phased logic-based scenario covering a 10-year span needs to be established to provide a production requirements baseline upon which to base estimated costs for future production. The scenario includes product quantities and production rates by calendar years for applicable product lines. This scenario provides the time-phased processing requirements to serve as baseline for estimates of future production costs employing either present-day or improved methods.

B). Costs

Work Breakdown Structures (WBS) and time-phased schedules need to be developed for each of the proposed modernization projects which identify the associated development and implementation costs. The WBS and schedules are then utilized to establish cost and schedule controls for the various elements of the total task.

Capital cost requirements need to be established on an individual project basis, and the time-phased acquisition determined by the development phase requirements.

Nonrecurring costs of capital acquisition, transportation, and equipment installation need to be included, but requires a centralized coordination effort to ensure the availability of funds consistent with the individual project needs and implementation schedules.

Any additional cost elements associated with implementing and maintaining modernization projects are included in the analysis of "Before IMIP" and "After IMIP" models.

C). Benefits

Cost estimates for potential savings resulting from implemented systems needs to be derived by assessing improved efficiencies and yields against reductions in required manpower projected to result from the automated systems. Detailed estimates need to be developed utilizing "Before IMIP" and "After IMIP" models at the project level and employing industrial engineering estimating techniques to establish future labor hours, costs, and equivalent manpower requirements for present-day and improved methods. Estimates need to be derived in accordance with the time phased schedule and encompass not only basic production and processing costs, but also costs of a supportive nature, such as equipment maintenance, calibration, and other non "hands-on" activities.

Additional production requirements need to be forecasted from existing product planning and a projection of future conventional processing needs in order to distinguish the effect of manufacturing technology on future costs.

Each technology modernization project needs to be analyzed to determine the effect on indirect cost categories such as labor, floorspace, work-in-process inventory, and associated equipment alternatives.

Improved processes and yields often generate additional factors in determining savings such as scrap/rework, materials, and energy. These factors need to be included in the individual project analysis.

D). System Implementation Plans

Implementation plans need to be established on an individual project basis and will be coordinated to ensure availability of resources.

Additional production requirements need to be forecasted from existing product planning and a projection of future conventional processing needs in order to distinguish the effect of manufacturing technology on future costs.

The estimated rate of return can then be calculated using the DCF/SSA model. The following generic factors influence the rate of return calculation and must be reviewed in detail for each specific business unit.

- Depreciation, expense, and cost of money are assumed to be recovered in the cost rate.
- Profit on depreciation and expense as well as retained savings for existing fixed-price contracts must be considered.
- Lost profit caused by reduced cost on future sales can be reclaimed under IMIP investments.
- Retained savings for commercial business must be considered under IMIP investments and/or new costing rates would be determined.

While the formula used to calculate the internal rates of return in various models is basically identical, disparities in the approach to the net cash flow calculations can occur. However, the net affect of each model will yield similar results given identical input. Figures 2-5 and 2-6 exemplify this point utilizing the Westinghouse IFPS and the LMI models.

FIGURE 2-5 LMI SAMPLE DCF MODEL

DISCOUNTED CASH FLOW MODEL (Version 1.00)

| | | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | --- | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Years | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | --- | 10 |
| **SECTION I. CORE DATA** | | | | | | | | | | | | | |
| 1 Contractor Investment | | 0.0 | 2,000.0 | 5,000.0 | 4,000.0 | 1,000.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | --- | 12,000.0 |
| Cumulative Total | | 0.0 | 2,000.0 | 7,000.0 | 11,000.0 | 12,000.0 | 12,000.0 | 12,000.0 | 12,000.0 | 12,000.0 | 12,000.0 | --- | |
| 2 Contractor Expenses | | 750.0 | 3,750.0 | 2,500.0 | 2,500.0 | 500.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | --- | 10,000.0 |
| Cumulative Total | | 750.0 | 4,500.0 | 7,000.0 | 9,500.0 | 10,000.0 | 10,000.0 | 10,000.0 | 10,000.0 | 10,000.0 | 10,000.0 | --- | |
| 3 DoD/Government Funding | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | --- | 0.0 |
| Cumulative Total | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | --- | |
| 4 Savings Available to DoD | | 0.0 | 250.0 | 5,000.0 | 5,250.0 | 5,500.0 | 10,000.0 | 10,500.0 | 12,000.0 | 12,500.0 | 15,000.0 | --- | 76,000.0 |
| Cumulative Total | | 0.0 | 250.0 | 5,250.0 | 10,500.0 | 16,000.0 | 26,000.0 | 36,500.0 | 48,500.0 | 61,000.0 | 76,000.0 | --- | |
| | | | | | | | | | | | | --- | |
| **SECTION II. INCREMENTAL CASH FLOWS** | | | | | | | | | | | | | |
| 5 Productivity Savings Reward | | 0.0 | 75.0 | 2,250.0 | 2,500.0 | 2,500.0 | 1,875.0 | 0.0 | 0.0 | 0.0 | 0.0 | --- | 9,200.0 |
| Cumulative Total | | 0.0 | 75.0 | 2,325.0 | 4,825.0 | 7,325.0 | 9,200.0 | 9,200.0 | 9,200.0 | 9,200.0 | 9,200.0 | --- | |
| 6 Cost of Money (CAS 414) | 10.38% | 0.0 | 90.8 | 395.5 | 745.7 | 855.9 | 732.2 | 596.6 | 440.9 | 285.3 | 142.7 | --- | 4,305.6 |
| 7 CAS 409 Depreciation | | 0.0 | 250.0 | 875.0 | 1,375.0 | 1,500.0 | 1,500.0 | 1,500.0 | 1,500.0 | 1,500.0 | 1,250.0 | --- | 11,250.0 |
| 8 Profit Effect | | 712.1 | 3,629.9 | 2,535.1 | 2,107.2 | 532.7 | (112.6) | (910.8) | (530.8) | (600.8) | (737.8) | --- | 7,204.2 |
| 9 Subtotal: DoD Cash Flows to Contractor | | 712.1 | 4,045.7 | 6,055.6 | 6,807.9 | 5,388.6 | 4,014.6 | 1,685.0 | 1,410.1 | 1,184.5 | 654.9 | --- | 31,959.8 |
| 10 Salvage Value | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | --- | 0.0 |
| 11 Contractor Before-Tax Cash Flow | | (37.9) | (1,704.3) | (1,444.4) | 307.9 | 3,888.6 | 4,014.6 | 1,685.0 | 1,410.1 | 1,184.5 | 654.9 | --- | 9,959.8 |
| | | | | | | | | | | | | --- | |
| **SECTION III. TAX CALCULATIONS** | | | | | | | | | | | | | |
| 12 ACRS Depreciation | | 0.0 | 100.0 | 800.0 | 1,620.0 | 1,900.0 | 1,760.0 | 1,520.0 | 1,280.0 | 1,040.0 | 800.0 | --- | 10,900.0 |
| 13 Contractor Taxable Income | | (37.9) | 115.7 | 2,675.6 | 2,687.9 | 2,988.6 | 2,254.6 | 165.0 | 130.1 | 144.5 | (145.1) | --- | 10,979.0 |
| 14 Contractor Income Tax | 46% | 17.4 | (53.2) | (1,230.0) | (1,236.4) | (1,374.8) | (1,037.1) | (76.3) | (59.9) | (66.5) | 66.0 | --- | (5,050.7) |
| 15 Investment Tax Credit | 8% | 0.0 | 160.0 | 400.0 | 320.0 | 80.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | --- | 960.0 |
| 16 Contractor After-Tax Cash Flow | | (20.5) | (1,597.5) | (2,275.2) | (608.5) | 2,593.9 | 2,977.5 | 1,609.5 | 1,350.3 | 1,118.0 | 728.6 | --- | 5,869.1 |
| Cumulative Total | | (20.5) | (1,618.0) | (3,893.1) | (4,501.7) | (1,907.8) | 1,069.7 | 2,679.2 | 4,029.4 | 5,147.5 | 5,869.1 | --- | 20.56% |
| | | | | | | | | | | | | --- | |
| **SECTION IV. SUMMARY** | | | | | | | | | | | | | |
| 17 DoD Program Benefit (Without Incentive) | | 0.0 | 250.0 | 5,000.0 | 5,250.0 | 5,500.0 | 10,000.0 | 10,500.0 | 12,000.0 | 12,500.0 | 15,000.0 | --- | 76,000.0 |
| Cumulative Total | 76000 | 0.0 | 250.0 | 5,250.0 | 10,500.0 | 16,000.0 | 26,000.0 | 36,500.0 | 48,500.0 | 61,000.0 | 76,000.0 | --- | |
| 18 DoD Program Benefit (With Incentive) | | 0.0 | 175.0 | 2,750.0 | 2,750.0 | 3,000.0 | 8,125.0 | 10,500.0 | 12,000.0 | 12,500.0 | 15,000.0 | --- | 66,800.0 |
| Cumulative Total | 66800 | 0.0 | 175.0 | 2,925.0 | 5,675.0 | 8,675.0 | 16,800.0 | 27,300.0 | 39,300.0 | 51,800.0 | 66,800.0 | --- | |
| 19 DoD Payback Period | 0.0 years | | | | | | | | | | | --- | |
| 20 Government Benefit | | (17.4) | 68.2 | 3,580.0 | 3,666.4 | 4,298.0 | 9,162.1 | 10,576.3 | 12,059.9 | 12,566.5 | 14,933.2 | --- | 70,890.7 |
| Cumulative Total | | (17.4) | 50.8 | 3,631.6 | 7,298.0 | 11,592.8 | 20,754.9 | 31,331.1 | 43,391.0 | 55,957.5 | 70,890.7 | --- | |
| 21 Government Payback Period | 1.3 years | | | | | | | | | | | --- | |
| 22 Contractor Internal Rate of Return | | | | | | | | | | | | --- | |
| Without Incentive | 3.0% | | | | | | | | | | | --- | |

FIGURE 2-6 IFPS SAMPLE DCF MODEL

MODEL TM VERSION OF 10/10/85 13:07 -- 11 COLUMNS 50 VARIABLES

10/29/85

SAMPLE ROI ANALYSIS REPORT

| | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 | YEAR 6 | YEAR 7 | YEAR 8 | YEAR 9 | YEAR 10 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EXPENSE | 750.0 | 3750.0 | 2500.0 | 2500.0 | 500.0 | | | | | | 10000.0 |
| EQUIPMENT | | 2000.0 | 5000.0 | 4000.0 | 1000.0 | | | | | | 12000.0 |
| BUILDING | | | | | | | | | | | |
| CASH FLOW ADJ | | | | | | | | | | | |
| CAPITAL | | 2000.0 | 5000.0 | 4000.0 | 1000.0 | | | | | | 12000.0 |
| TOTAL INVESTMENT | 750.0 | 5750.0 | 7500.0 | 6500.0 | 1500.0 | | | | | | 22000.0 |
| INCENTIVE SAVINGS | | 75.0 | 2250.0 | 2500.0 | 2500.0 | 1875.0 | | | | | 9200.0 |
| DEPR RECOVERY | | [illegible] | 500.2 | [illegible] | [illegible] | [illegible] | 1410.0 | 1410.0 | 1410.0 | 1290.4 | [illegible] |
| EXP RECOVERY | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | | | | [illegible] |
| DEPR PROFIT | 42.3 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| SAVINGS LOSS | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| COST OF MONEY | | 91.4 | 399.2 | 755.0 | [illegible] | [illegible] | [illegible] | 487.6 | 341.3 | 201.1 | 4565.4 |
| RETAINED SAVINGS | | | 50.0 | 75.0 | 300.0 | 600.0 | 650.0 | 650.0 | 700.0 | 750.0 | 3775.0 |
| IBT | 42.3 | 412.3 | 2775.5 | [illegible] | [illegible] | [illegible] | 223.1 | -43.2 | -259.5 | [illegible] | [illegible] |
| IAT | 22.0 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 120.5 | -23.3 | -140.1 | [illegible] | [illegible] |
| INVEST CREDIT | | [illegible] | [illegible] | [illegible] | [illegible] | | | | | | [illegible] |
| ACC DEPR TAX ADJ | | [illegible] | 313.6 | [illegible] | 535.2 | 516.6 | 317.4 | -165.6 | -552.0 | -597.3 | [illegible] |
| EXPENSE TAX ADJ | 36.9 | 160.4 | 42.0 | 69.0 | -29.4 | -10.0 | | | | | 276.0 |
| NET CASH FLOW | -20.5 | -1616.7 | -2320.7 | -550.8 | 2791.7 | 3296.6 | 1047.9 | 1221.1 | 717.9 | 411.3 | 5761.8 |
| IRR | 25.5 | | | | | | | | | | |
| GOVT SAVINGS | | 250.0 | 5000.0 | 5250.0 | 5500.0 | 10000.0 | 10500.0 | 12000.0 | 12500.0 | 15000.0 | [illegible] |
| COMM SAVINGS | | | 50.0 | 75.0 | 300.0 | 600.0 | 650.0 | 650.0 | 700.0 | 750.0 | 3775.0 |
| MAJOR PROG SAVINGS | | 150.0 | 4500.0 | 5000.0 | 5000.0 | 7500.0 | 9000.0 | 9500.0 | 10000.0 | 10500.0 | 61150.0 |

C. Applications of Each Model

3. MFPMM

The MFPMM is intended to compliment and integrate with a management team's planning, measurement and evaluation, and control and improvement process. There are many different potential applications for the model. Certain applications require software revision and development, however, this has not been a major problem. Ultimately, we believe this model or derivations will become an integral part of a top management team's management support system. We envision condensed and summarized data from the model being used throughout the organization, including at the Board of Director level.

The ideal application for the MFPMM and the current software is at the plant level. The model is best suited for an application with an operation that has discrete products, with short cycle times, few product mix changes, and few design changes. An example of a perfect application for the model is a food processing plant with a stable product line. This example is not intended to infer that other applications are not possible. The LTV/VAPD application is an example of how the model can be successfully modified to work in even the most difficult of measurement situations.

Experience suggests that the MFPMM is quite simple to implement in ideal applications. The model has been quite successfully modified and implemented at a reasonable cost in long-cycle time, many product mix changes, many product design changes situations. The LTV/VAPD application of the model has required 1.5 person-years of effort to develop.

An application scenario for the model is provided in the LTV/VAPD description of their use of the model. An additional applications scenario is as follows. Once a quarter, the model is run with new data. The model output is sent to the management and staff team responsible for the operation. Each management team member is asked to analyze and interpret what the model suggests has happened to the performance of the operation. Each team member would also be asked to come to the review meeting with specific plans designed to improve the performance of the operation during the next quarter. Specific interventions would be entered into the model's simulation routine (pessimistic, most likely, optimistic values for changes can be entered to account for uncertainty). The model can be run for various combinations of improvement interventions. Productivity improvement strategies can then be built into challenge budgets. LTV/VAPD utilizes a version of this process. The model is run with annual budget data and updated with quarterly actual data. They incorporate forecasted budgets five years out in the model.

The MFPMM application appears to be limited primarily by a resistance or reluctance on the part of American management to experiment with and develop advanced and improved decision support systems. MFPMM applications such as the one being developed by LTV/VAPD are exemplary of excellent management practices.

## D. Comparison and Evaluation Methodology

### 1. Generic Criteria

The purpose of this study was to test three specific models that were viewed as having potential to measure and evaluate productivity (effectiveness, quality, efficiency) and, to support specific government to contractor incentive methodology (e.g., IMIP). As mentioned, none of the individual models was designed specifically to satisfy the goals desired by DoD. However, we have developed a set of generic criteria that should be used to evaluate productivity management methodologies. Table V-D-1-1 lists these criteria. We have also developed a set of generic criteria that should be used to evaluate specific models that might be applied for the purpose of measuring and evaluating productivity and supporting incentive methodologies. Table V-D-1-2 lists those criteria. In the next section, V-D-2, we present the sets of specific criteria or design specifications that each of the three models were intended to meet. In Section V-E we then evaluate each model against the criteria listed in Table V-D-1-2 (generic productivity measurement and evaluation and incentive methodology support system criteria). In Section V-F we evaluate the LTV/VAPD productivity management methodology against the criteria listed in Table V-D-1-1 (generic productivity management methodology). We do not evaluate each model against its own design criteria as we suspect/hope the results are obvious.

Table V-D-1-1 Generic Criteria Useful in Evaluating Productivity Management Methodologies (PMGC)

| | |
|---|---|
| $PMGC_1$ | • Does the methodology incorporate a 2-5 year strategic planning process? |
| $PMGC_2$ | • Does the planning process, by which the 2-5 year plan is developed, substantively involve all major, relevant, and appropriate key decision makers in the organization? |
| $PMGC_3$ | • Does the methodology recognize the need for a competent "champion"? |
| $PMGC_4$ | • Does the methodology incorporate mechanisims for managing change within a political and sociological culture? |
| $PMGC_5$ | • Does the methodology ensure that productivity basics are understood consistently by all persons in the organization? |
| $PMGC_6$ | • Does the methodology consider and incorporate a process by which general awareness about the win-win features of productivity improvement can be developed? Does the methodology recognize that there are strong pressures/restraining forces impeding productivity improvement that must be forthrightly and openly dealt with? |
| $PMGC_7$ | • Does the methodology incoporate the notion of stages of development or evolution for the productivity effort? |
| $PMGC_8$ | • Is there genuine, real, long-lasting top management support for the effort? Does the methodology provide a mechanism for getting and keeping the support? |
| $PMGC_9$ | • Does the methodology adequately provide for integration of specific models, techniques, and steps within the methodology and a mechanism for integrating these with other management systems? |
| $PMGC_{10}$ | • Does the methodology define how the productivity management plan will integrate with the business plan, marketing plan, capital budgeting plan, long-range (5-25 year) strategy plan, etc.? |
| $PMGC_{11}$ | • Does the methodology utilize state-of-the-art participative management techniques, at all levels of management, to drive productivity improvement plans? |

Table V-D-1-1 (cont.)

| | |
|---|---|
| $PMGC_{12}$ | • Does the methodology specifically deal with how to link strategic productivity improvement planning to action planning and effective implementation? |
| $PMGC_{13}$ | • Does the methodology incorporate mechanisims that encourage and promote disciplined management of budgets (all resources) at various levels of management and supervision? |
| $PMGC_{14}$ | • Does the methodology incorporate continuing and proactive development of improvement measurement and evaluation systems? Does the methodology specifically incoporate state-of-the-art productivity measurement and evaluation techniques? |
| $PMGC_{15}$ | • Does the methodology strongly encourage periodic measurement and evaluation system audits that check to ensure that those things which truly constitute system performance are measured? |
| $PMGC_{16}$ | • Does the methodology recognize the difference between measurement and evaluation systems for control purposes versus those for development and improvement purposes? |
| $PMGC_{17}$ | • Does the methodology discourage measuring A while hoping for B? |
| $PMGC_{18}$ | • Does the methodology define how various measurement and evaluation systems will integrate into a cohesive, effective management system that supports proactive productivity management? |
| $PMGC_{19}$ | • Does the methodology allow for personalized scoreboard building by sections, work groups, departments, etc.? |
| $PMGC_{20}$ | • Does the methodology promote continuing, proactive development of control and improvement techniques related to all resorces? Does the methodology specifically incorporate state-of-the-art productivity control and improvement approaches and techniques for labor, capital, energy, materials, and data/information? |
| $PMGC_{21}$ | • Does the methodology encourage periodic audits of control and improvement procedures? Do we audit what we really reward? |
| $PMGC_{22}$ | • Does the methodology discourage rewarding A while hoping for B? |

Table V-D-1-1 (cont.)

| | |
|---|---|
| $PMGC_{23}$ | • Does the methodology encourage and promote innovation at all levels of the organization? |
| $PMGC_{24}$ | • Does the methodology utilize a "cost-driver" analysis to identify where improvement efforts are best directed? |
| $PMGC_{25}$ | • Does the methodology define how to successfully link control and improvement to measurement and evaluation, and vice versa? |
| $PMGC_{26}$ | • Does the methodology focus on building effective management systems as opposed to just automating? Are our improvement efforts piecemeal attempts to optimize subsystems at the expense of larger system performance? |
| $PMGC_{27}$ | • Does the methodology strive to create goal-conguity/win-win situations? If the organization wins, will the individual win also? |
| $PMGC_{28}$ | • Does the methodology successfully utilize state-of-the-art participative management techniques for productivity improvement plan identification, development, and implementation? |
| $PMGC_{29}$ | • Does the methodology focus on execution of management basics as an early step in productivity improvement? |
| $PMGC_{30}$ | • Does the methodology hold management, staff, and employees accountable in a disciplined, consistent fashion? |
| $PMGC_{31}$ | • Does the methodology incoporate planning for maintaining excellence once it is achieved? |
| $PMGC_{32}$ | • Do all levels of management and staff understand the methodology? Does the methodology incoporate plans to involve management in its development and to continue education as to the methodologies execution? |
| $PMGC_{33}$ | • Is the methodology designed so as to be self motivating? |
| $PMGC_{34}$ | • Is the methodology as simple as possible? |

Table V-D-1-2 Generic Criteria Useful in Evaluating Productivity Measurement and Evaluation Models that will also Support Incentive Methodology*
(PMEM GC)

| | |
|---|---|
| $PMEMGC_1$ | • Is the model easy to use?<br>- Ease of Application |
| $PMEMGC_2$ | • Ease of Application for Prime Contractors.<br>• Ease of Application for Subcopntractors. |
| $PMEMGC_{3a}$ | • Does model utilize existing company data bases?<br>- Percent of data needed that is available. |
| $PMEMGC_{3b}$ | • Does the model require developing new company data bases? If needed data is not available, can model be modified to provide valuable information?<br>- New data bases that <u>must</u> be developed to use model. |
| $PMEMGC_{4a}$ | • What does the model measure? (directly & indirectly)<br>- Effectiveness<br>- Efficiency<br>- Quality<br>- Productivity<br>- Quality of Work Life<br>- Innovation<br>- Profitability |
| $PMEMGC_{4b}$ | • Is the model primarily designed for:<br>- cost/benefit, cash flow projection and analysis?<br>- cost/benefit, cash flow tracking & validation?<br>- productivity measurement & evaluation?<br>- a control tool?<br>- an improvement tool?<br>- a department, function, or workgroup analysis tool?<br>- a plant, division, or company analysis tool?<br>- a project or program analysis tool? |
| $PMEMGC_5$ | • Model usefulness for Manufacturing Efficiency Projects? for Manufacturing Investment Projects? |
| $PMEMGC_6$ | • Implementation Costs?<br>- general magnitude<br>- design & development<br>- implementation<br>- operation and maintenance |

* Incentive Methodology in this application infers Government to Contractor Incentive Systems such as IMIP.

Table V-D-1-2 (cont.)

| | |
|---|---|
| $PMEMGC_7$ | • Ability to measure and allocate savings to multiple programs? |
| $PMEMGC_8$ | • Ability to have productivity improvement projects and business programs added and deleted? Flexibility of model? |
| $PMEMGC_9$ | • Ability to delineate commercial and government program benefits? |
| $PMEMGC_{10}$ | • Quality of model output? Appropriateness of model output portrayal? Flexibility of output for variable audiences? |
| $PMEMGC_{11}$ | • Accessibility of necessary input data? Preprocessing of input data required? |
| $PMEMGC_{12}$ | • Auditability of model? |
| $PMEMGC_{13}$ | • Ability of model to handle long cycle times, multiple products, frequent design changes, product mix changes? |
| $PMEMGC_{14}$ | • Ease of translation and transfer of model within defense industry? |
| $PMEMGC_{15}$ | • Perceived complexity of model? |
| $PMEMGC_{16}$ | • Ability of model to satisfy needs of multiple users (i.e., Congress, DoD, contractor, managers, staff, etc.)? |
| $PMEMGC_{17}$ | • Uniqueness and perceived utility of information provided by model? |
| $PMEMGC_{18}$ | • Perceived implementation cost? |
| $PMEMGC_{19}$ | • Ease of linkage, and quality of the link between what the model measures and incentive methodology? |
| $PMEMGC_{20}$ | • Model's conformance to accepted cost accounting practices? |
| $PMEMGC_{21}$ | • Does the model follow functional (organizational chart) analysis or a cost-structured approach? |
| $PMEMGC_{22}$ | • Model's allowance for comparing and contrasting "As Is and As Were" cost baselines vs. "To Be" cost baselines? |

Table V-D-1-2 (cont.)

| | |
|---|---|
| $PMEMGC_{23}$ | • Ability of model to incorporate uncertainty and risk? |
| $PMEMGC_{24}$ | • Ability of model, using existing data, to track productivity improvement? |
| $PMEMGC_{25}$ | • Ability of model to treat multi-dimensionality of performance and productivity, i.e., ability of model to examine cost factors and non-economic factors? |
| $PMEMGC_{26}$ | • Ability of model to substantively involve users and people in the system in its development, evolution and use? |
| $PMEMGC_{27}$ | • Ability of model to guide, direct, and even motivate action and implementation? |
| $PMEMGC_{28}$ | • Ability of model to support decisions? |
| $PMEMGC_{29}$ | • Ability of model to satisfy the goals of DoD and contractors? |
| $PMEMGC_{30}$ | • Ability of model to be integrated successfully into typical defense industry management systems? |

D. Comparison and Evaluation Methodology

2. Specific Criteria

CDEF: a) Has a functional structure been used?

b) Have function groups been identified?

c) Has the financial reporting structure been "mapped" against the functional structure?

d) Has a comprehensive Manufacturing Cost Model been identified?

e) Have Critical Success Factors and the related performance measures been identified?

f) Have "as is" and "to be" cost baselines been established?

g) Has project risk been considered?

h) Has the synergistic impact of the technology improvements been considered?

i) Has a benefits tracking plan been developed?

MFPM: Does the model:

a) provide an overall, integrated measure of productivity for a plant, division, firm, etc.?

b) provide an analytical mechanism for evaluating past performance?

c) provide important information for budget control?

d) provide constant value information on performance?

e) assess and evaluate bottom-line impact on profits from shifts in productivity and price-recovery?

f) track results of specific productivity improvement interventions or track total results of all productivity improvement interventions?

g) assist with establishment of productivity management planning?

h) provide in a succinct, integrated report containing information related to
   - changes in resource utilization and output composition.
   - traditional "pie chart," cost driver analysis data.
   - partial factor, multi-factor, and total productivity ratios.
   - performance indexes, changes in productivity, price-recovery and profits from period to period.
   - the constant-value dollar impact of productivity and. price-recovery changes on profits.

i) provide management teams with the ability to forecast and simulate business conditions, cost patterns, productivity trends, and to analyze these changes (controlled, constrained or otherwise ) on overall performance.

j) notivate more proactive productivity management efforts on part of management teams.

k) reflect good management system design (i.e., consider who is managing and what is being managed in relation to what we are managing with).

l) promote total factor (energy, capital, labor, materials, data/information) productivity management decision-making.

DCF/SSA: a) Has a top-down structured factory wide analysis been performed?

b) Have structured cost benefits analysis (CBA) methods been utilized?

c) Is the CBA in compliance with cost accounting standards, contractor disclosure statements, and negotiated rates and factors?

d) Has an acceptable range of returns been considered both with and without incentives?

## E. Evaluation of Each Model as a Productivity Measurement and Evaluation Model that can be Linked to Incentives Methodology

In this section, each of the three models have been evaluated against the thirty plus generic criteria which were listed in Table V-D-1-2 previously. This evaluation is, in some cases, based upon hard data previously available or developed during the paper tests. However, in other cases, the evaluation represents the subjective wisdom of the PI and, to a large extent, the collective judgment of the research team. Although such an evaluation was called for in the RFP, the reader/evaluator is urged to keep in mind that none of these three models were designed specifically to measure productivity in the defense contractor environment or to support incentive methodology. In this respect, the evaluation must be viewed as a somewhat academic exercise. The analysis is provided so that the reader may view the research team's perception of how each model performs against these criteria.

Table V-E-1 is provided to give an overall and general evaluation of each model against these thirty criteria. This evaluation is very brief and, as stated previously, is largely subjective and qualitative. A more quantitative evaluation of each model can be found in Section VII. Immediately following Table V-E-1 is a specific evaluation of Price Waterhouses's CDEF model by Price Waterhouse.

TABLE V-E-1

| | MFPMM | CDEF | DCF(LMI) |
|---|---|---|---|
| 1 Ease of Use | Moderate | Moderate (Involved) | Moderate (Simple) |
| 2 Ease of Use: Primes | Variable - depends on Management Systems | Variable - complexity a factor | Moderate to Simple |
| Ease of Use: Subs | Variable - depends on Management Systems | Variable - complexity a factor | Variable |
| 3a Data Availability | Good at Macro Analysis | Available from General Ledger | Good, but requires estimation |
| 3b Data Base Development | Not necessary for LTV type application | Necessary only for entry into ACBG | Necessary in some areas |
| 4a Measure: Effectiveness | Not Directly | Yes | Indirectly |
| Efficiency | Indirectly | Yes (costs) | Projects |
| Quality | Indirectly | No | Not Directly |
| Productivity | Directly | No | No |
| Quality of Work Life | No | No | No |
| Innovation | Very Indirectly | Impact of Mftg.Improve. | Projects Impact |
| Profitability | Directly | Yes (costs) | Yes |
| 4b Focus: Cost/Benefit Analysis | Indirectly | X | X |
| Cost/Benefit Tracking | Indirectly | X | No |
| Productivity Measurement & Evaluation | X | Evaluation only | Indirectly |
| Control | X | X | No |
| Improvement | X | X | No |
| Group/Function | No | X | No |
| Plant/Firm | X | X | No |
| Project/Program | Might be difficult | X | X |
| 5 Useful for: (a) Modernization Efficiency Projects | X | X | Not Intended Focus |
| (b) Modernization Investment Projects | X | X | X |
| 6 Implementation Costs | | | |
| Design & Development | Mod | Variable | Lo |
| Implementation | Lo | Lo | Lo |
| Operations and Maintenance | Lo | Lo | Lo |
| 7 Measure & Allocate Savings to Multiple Programs | Yes, via multiple model design | Yes, via multiple model variations | N/A |
| 8 Flexibility | Good in LTV Type Applic. | Good once sys. set up | Good |

TABLE V-E-1

| | MFPMM | CDEF | DCF(LMI) |
|---|---|---|---|
| 9 Commercial vs. Government | Depends on data avail. | Yes | ? |
| 10 Output Quality | Needs Improvement | Needs Improvement | Needs Improvement |
| 11 Access of Input Data | Good in LTV-type Application | Variable | Estimation & Base Line Data |
| 12 Auditability | Good | Good | Good |
| 13 Appropriateness in Typical Defense Setting | Requires Modification | Good | Designed for Setting |
| 14 Translation & Transfer | No Data | Situation specific | Transferable |
| 15 Perceived Complexity | Moderate | Hi | Moderate |
| 16 Satisfy Multiple Users | Feasible | Feasible | Feasible |
| 17 Utility of Info. Provided<br>Uniqueness of Info Provided | Not Clear<br>Hi | Varies<br>Hi | To Govmt. Yes/Client?<br>Mod-Lo |
| 18 Perceived Implementation Cost | Moderate | Variable | Mod |
| 19 Link to Incentive Methodology | Very Good at Macro | Good | Very Good |
| 20 Conform to Accounting (GAAP/CASB) | Possible | Forced/Yes | Forced |
| 21.Functional (org.chart) vs. Cost Structure | X LTV Applic.<br>X Possible | X | Complies with CAS<br>X |
| 22 "As Is" to "To Be" Comp. | Yes | Yes | Yes |
| 23 Incorp. Uncert. & Risk | Yes | Yes | Not Clear/Possible |
| 24 Track Prod. Imp. | Yes | CBT Data Available/Yes | No |
| 25 Multi Dimensionality | Yes (Partial) | Yes | No |
| 26 User Involvement | Not High in LTV Application | Variable/Depends | Lo |
| 27 Motivate Improvement | Possible, not high in LTV Applic. | Depends on Application | Yes, with incentive |
| 28 Support Decisions | Yes | Yes | Yes |
| 29 Satisfy DoD?<br>Contractors? | Possible<br>Limited Data | Yes<br>Variable | Needs Enhancement<br>Not Clear Yet |
| 30 Integratable into Mgmt Systems | Yes | Yes | Assume there already<br>Yes |

## PAPER TEST METHODOLOGY

The Paper Test Methodology for Price Waterhouse's CDEF methodology was threefold: 1) preparing background and briefing materials for LTV personnel; 2) conducting a one-day in-plant review of the CDEF methodology; and 3) preparing an analysis of the applicability of CDEF to the test site.

### Background and Briefing Materials

We forwarded to Mr. Shoni Dhir a briefing package as a preliminary agenda for the in-plant meeting. (See Appendix 6.) Five tasks were outlined:

1) Review of topics presented by LTV at the August 1985 meeting;

2) Review of Price Waterhouse's CDEF methodology;

3) Determination of the differences between LTV's cost-benefit analysis and tracking methodology(ies) and Price Waterhouse's CDEF methodology;

4) Determination of the level of effort required to reconcile differences in the two methodologies; and

5) Determination of enhancements to both approaches.

Included in Task 3 was a description of the nine criteria PW uses to review how a company should conduct cost-benefit analysis and cost-benefit tracking. Three key concepts are highlighted in this document which characterize a comprehensive cost-benefit methodology:

1) It should evaluate cost and performance impacts of enhanced manufacturing technology programs for manufacturing functions or activities rather than on a part or product basis.

2) It should prepare an analysis of, and a plan to minimize, project risk (economic, technical, and human factors).

3) It should identify cost-benefit tracking requirements to aid in assuring realization of proposed benefits.

## Review of the CDEF Methodology

The Price Waterhouse project team (Gene Klein and Betty Thayer) met with the LTV IMOD Cost-Benefit Team (Ray Thornton and Len Thorpe) on Tuesday, October 15, 1985 to discuss the potential application of CDEF at LTV. Dr. Marvin Agee from VPI was also in attendance. This meeting was critical to furthering the understanding of data availability at LTV.

## Analysis of the CDEF Methodology at the Test Site

To expedite the use of the CDEF methodology, Price Waterhouse has developed an application software tool, the Automated Cost Baseline Generator (ACBG). Due to the quantity of calculations required in the CDEF process, ACBG allows the cost-benefit team to concentrate on the methodology being used and validity of data, rather than the tasks of computation. For the purposes of this study, ACBG and its features were not evaluated. Simply stated, one could not operate ACBG unless the CDEF methodology was completely understood. Unfortunately, the LTV team chose to paper test only the ACBG portion of CDEF; therefore, comparing the two paper tests may be confusing.

For the purposes of this study we have tailored our nine cost-benefit criteria to include shared savings analysis. Figure A provides an analysis of the requirements for implementing CDEF at the LTV test site.

Attachments 1 through 5 are the items discussed at the paper test site visit.

## ANALYSIS OF THE CDEF METHODOLOGY AT THE TEST SITE

| ATA REQUIREMENTS PRICE WATERHOUSE CDEF ETHODOLOGY | LTV DATA AVAILABILITY | ADDITIONAL DATA REQUIREMENTS |
| --- | --- | --- |
| . <u>Structure</u><br><br>CDEF uses a top-down functional/activity structure similar to IDEFo modeling. Functions/activities are identified for the company (or business unit) and serve as a basis for determining and measuring cost and performance. Generally, six or more levels of activity are identified. | 1. <u>Structure</u><br><br>LTV utilizes the current organization structure for cost analysis. Organizations serve as the basis for determining and measuring cost and performance. Activities are identified for each organization and those supporting organizations. | 1. <u>Structure</u><br><br>Functions/activities would need to be identified (which will cross current organization boundaries). These functions/activities would then have to be assimilated into a top-down function/activity structure. |
| 2. <u>Function Groups</u><br><br>Once the node tree diagram is developed, individual nodes are grouped into Functional Groups (synergistically related nodes that will be impacted by a <u>single</u> improvement program). | 2. <u>Function Groups</u><br><br>Improvement projects are assigned to one organization and are not identified as having cross-organizational impacts, except when those impacts occur in supporting organizations. | 2. <u>Function Groups</u><br><br>Once a node tree diagram is developed, Function Groups which are impacted by a given technology program would have to be identified. |
| 3. <u>Manufacturing Cost Model (MCM) and Performance Criteria</u><br><br>The MCM allows for grouping costs on a common basis for calculating the "As Is" and "To Be" baselines. A typical MCM groups costs by material segments, labor segments, and overhead and support segments. | 3. <u>Manufacturing Cost Model</u><br><br>LTV groups costs for a given organization and its supporting organizations. | 3. <u>Manufacturing Cost Model</u><br><br>An MCM which is designed to capture functional cost would have to be developed. |
| 4. <u>"As Is" Baseline</u><br><br>CDEF uses actual financial information via the general ledger and its feeder systems for establishing "As Is" or "current" cost baselines. General ledger information provides an auditable and consistent data base. Actual current costs are collected and assigned to appropriate functions/activities using the MCM. Costs that are normally maintained at the organizational level are also mapped to the appropriate functions/activities. (Function Groups). | 4. <u>Cost Baseline</u><br><br>LTV uses actual organizationally based information from the financial reporting system. | 4. <u>"As Is" Baseline</u><br><br>Organizational costs, as reported via the general ledger and its subsidiary systems, would have to be mapped to the appropriate functions/activities defined in (2.). |

| DATA REQUIREMENTS PRICE WATERHOUSE CDEF METHODOLOGY | LTV DATA AVAILABILITY | ADDITIONAL DATA REQUIREMENTS |
|---|---|---|
| 5. Improvement Program Analysis<br>Improvement programs and associated technologies are measured, identified and tracked based on the impacts to the various functions/activities for both cost and performance. | 5. Improvement Program Analysis<br>Improvement programs are evaluated and measured based on the impact to a specific organizational cost or performance driver. | 5. Improvement Program Analysis<br>Improvement programs would need to be evaluated based on cost and performance measurement criteria established at the function/activity level. |
| 6. Cost-Benefit Projections<br>Costs and benefits for improvement program impacts ("To Be" analysis) are estimated for each relevant function/activity. These cost and benefit projections are developed on a comparable basis with the "As Is" baseline described in (4.). | 6. Cost-Benefit Projections<br>Costs and benefits for improvement program impacts are estimated on an organizational basis and tied to a specific activity for an organization and its supporting organizations. | 6. Cost-Benefit Projections<br>Estimates of the costs and benefits of the improvement program would have to be mapped to the appropriate functions/activities defined in (2.). |
| 7. Risk Considerations<br>Project risk is anticipated for economic, technology and human factors implications. Technology and human factors risks are analyzed and estimated at the function/activity level. Economic risk is analyzed at the project level. Costs and benefits identified in (6.) are adjusted based on this risk analysis. | 7. Risk Considerations<br>LTV currently does not evaluate and adjust specifically for economic, technology and human factors risk. General risks are identified and probabilities assigned to benefits. | 7. Risk Considerations<br>A risk management methodology would have to be developed which includes methods for identifying, quantifying and monitoring economic, technology and human factors risks. |
| 8. Synergistic Impacts<br>Whenever new technologies are implemented, their impact is rarely restricted to one node. This step evaluates the impact of a technology on multiple nodes and of multiple technologies on multiple nodes. | 8. Synergistic Impacts<br>LTV accounts for synergistic impacts only for two or more projects that impact the same organization (or supporting organizations), but not horizontally across organizations. | 8. Synergistic Impacts<br>After the node diagram is developed synergistic impacts would have to be identified. |

| DATA REQUIREMENTS PRICE WATERHOUSE CDEF METHODOLOGY | LTV DATA AVAILABILITY | ADDITIONAL DATA REQUIREMENTS |
|---|---|---|
| 9. Benefits Tracking<br><br>Once the improvement program is implemented, cost and performance are tracked on a function/activity basis. The result is an "Actual" baseline. | 9. Benefits Tracking<br><br>Once the improvement program is implemented, cost and performance are tracked on a basis equivalent to the "As Is" and "To Be" calculations. The result is an "Actual" baseline. | 9. Benefits Tracking<br><br>Again, actual costs and benefits of the improvement program would have to be mapped to the functions/activities defined in (1.). |
| 10. Project Savings<br><br>The difference between the "As Is" and actual baselines, adjusted for risk, would be the potential shared savings. | 10. Project Savings<br><br>The difference between the actual and the baseline is used to determine actual savings. These savings are then allocated to specific programs to determine shared savings. | 10. Project Savings<br><br>The risk management methodology (7.) would have to be applied to projected savings before actual savings are calculated. |

F. Evaluation of Combined Models Approach (Evaluation of LTV/VAPD Methodology

LTV/VAPD has developed, and is continuing to develop, a methodology for productivity management that combines and integrates a variety of models. Their methodology is quite adequately described in Section V of this report. We have evaluated their methodology against the criteria developed and listed in Table V-D-1-1. Again, our evaluation is subjective and based upon rather limited exposure. However, we felt an evaluation of this exemplary methodology would be useful. Table V-F-1 lists the criteria down the left side of the table and the major models that make up the methodology across the top of the table. For each criteria, a check in a given model column (cell) indicates that the model is designed to address this criteria. Overall methodology comments relative to a given criteria appear in the final column of the table.

Table V-F-1

LTV/VAPD Methodology

Models:

| Criteria: | NGT | TPM | Cost-Driver Analysis | MCPM | DCF | Challenge Budgets | Overall System General Comments |
|---|---|---|---|---|---|---|---|
| 1. 2-5 Plan Process | | ✓ | | | | ✓ | |
| 2. Plan Process Involvement of KDM's | | | | | | | Yes |
| 3. Champion | | | | | | | Yes |
| 4. Managing Change | | | | | | | Yes-Council |
| 5. Productivity Basics | | | | | | | Needs Improvement |
| 6. Productivity Restraints dealt w/ | | | | | | | Needs Improvement |
| 7. Stages of Evolution | | | | | | | Yes |
| 8. Top Mgmt. Support | | | | | | | Good-Productivity Council |
| 9. Integration into Mgmt. Sys. | | | | | | | Very Good |
| 10. Integration of Planning Sys. | | | | | | | Very Good |
| 11. Participative Mgmt. | | | | | | | Needs Improvement |
| 12. Link Planning to Implem. | | | | ✓ | | ✓ | Very Good |
| 13. Budget Mgmt. | | | | ✓ | | ✓ | Excellent |
| 14. Prod. Measurement Sys. Dev. | | | | | | | Excellent |
| 15. Meas. Audits | | | | | | | Needs Improvement |
| 16. Control vs. Tmp. Meas. & Eval. | | Planning | Improve. | Improv. | Plann. | Control | Excellent |
| 17. Meas. A While Hope for B | | | | | | | Yes |
| 18. Meas. & Eval. as Mgmt. Sys. | | | | | | | Excellent |
| 19. Personalized Scoreboards | | | | ✓ | | | Needs Development |
| 20. Control & Improve. Sys. Dev. | ✓ | ✓ | ✓ | | | ✓ | Yes |
| 21. Audit C&I Sys's | | | | | | | Needs Development |
| 22. Reward A While Hope for B | | | | | | | Rewards Need Development |
| 23. Innovation Promoted | ✓ | | | | | | Needs Development |
| 24. Cost-Driver Analysis | | | ✓ | | | | Excellent |
| 25. M&E + C&I | ✓ | ✓ | ✓ | ✓ | | ✓ | Excellent |
| 26. Sys. Optimization | | | | | | | Very Good |
| 27. Win/Win Situations Set Up | | | | | | | Needs Development |
| 28. Part. Mgmt. | ✓ | | | ✓ | | | Needs Improvement |
| 29. Mgmt. Basics | | | ✓ | | | ✓ | Good |
| 30. Accountability | | | | ✓ | | ✓ | Good |
| 31. Maintain Excellence | | | | | | | Shared Savings-Gainsharing |
| 32. Mgmt. Understanding | | | (councils | promote | this) | | Needs Improvement |
| 33. Self Motivating | | | | | | | Yes |
| 34. Simplicity | | | | | | | Comprehensive, But Not Simple |

# VI. RECOMMENDATIONS AND CONCLUSIONS

## A. Recommendations and Conclusions According to Major Objectives of Study

For the purpose of this study, conclusions and recommendations are summarized and grouped according to major objectives of the study:

01: Evaluate the ease of measuring and evaluating productivity using the CDEF, MFPMM, and DCF(LMI) models in "paper test" fashion.

06: Evaluate the abilities of the models, in paper test application, to satisfy overall project goal (i.e., to identify and develop productivity measurement and evaluation methodologies and models that will effectively integrate with government to contractor incentive methodologies).

08: Recommend (not develop) modifications, if any, to each model which would make them:
  a) easier to use
  b) easier to control
  c) easier to administer
  d) easier to obtain information, and
  e) easier to use in incentives/rewards applications.

09: Recommend whether or not to conduct a field test. Justify recommendation.

Several general recommendations and conclusions are also provided.

### 01. <u>EASE OF MEASURING AND/OR EVALUATING PRODUCTIVITY</u>

<u>CDEF</u>

Based upon numerous conversations with LTV personnel, the following conclusions have been reached regarding the ease of measuring and/or evaluating productivity for the purpose of the paper test:

- The structure of the LTV organization and the backgrounds of the LTV team members facilitated the evaluation of CDEF. LTV measures productivity on an organizational basis, which is fairly typical of aerospace companies. Consequently, the concepts and measurement techniques inherent to the CDEF methodology were easily explained to the LTV team.

- The information required to implement CDEF is available at LTV. Actual data sources, however, were not identified. Collection of such data would require the development of a parallel (or separate) data base which the productivity team could manipulate.

- Specific tasks that the project team would have to undertake in order to implement the CDEF methodology include the following:
  - Augment the IMOD Productivity Team staff with an individual familiar with the financial reporting system and general ledger accounts.
  - Prepare a functional node tree diagram and corresponding Function Groups of the Division.
  - Identify and document the critical cost and performance measurements for all functions (or Function Groups).
  - Link the financial reporting system and cost and performance measurements to the benefits tracking plan.

MFPMM

LTV/VAPD utilizes a modified version of the MFPMM as discussed in Section VII. They measure and evaluate productivity at the Division and Function level with this model. The data they use to drive the model is readily available and they have encountered no major difficulties using the model. The model does, however, require continued developmental effort to "fine tune" certain critical aspects.

DCF(LMI)

The discounted cash flow model (both the LMI and Westinghouse versions) is an end-result, aggregate productivity measurement/evaluation model, primarily applicable at the project level. It is thus a narrow-scope productivity measurement/evaluation "model", and perhaps should be termed a technique rather than a model. Productivity is measured in that the model calculates an input (capital investment) and output (annual savings, or revenues) relationship. Productivity is evaluated by virtue of the calculated Rate of Return (ROI) that results from the input-output relationship. The ROI calculated for a particular project is then compared to a desired minimum attractive rate of return, or "hurdle" rate, to judge economic feasibility for the project.

As an end-result productivity measurement/evaluation model, the general DCF cash flow model (not the specific LMI and Westinghouse versions for IMIP purposes) is easy to use since this methodology is a well-known, straight-forward economic analysis technique. Any difficulty in use arises from all the "outside-the-model" estimations and calculations required to determine the capital investment required and any resulting annual savings, or revenues over some arbitrarily defined planning horizon of interest.

The specific DCF model subjected to the paper-test at LTV/VAPD, both the LMI and Westinghouse versions, are judged not very easy to use. Since the Westinghouse version is company-specific, the LMI version is assumed to be the DoD standard. This being the case, then the "standard" DCF model is judged very difficult to use, primarily because the available User's Manual is incomplete and sparse in the information supplied.

Additionally, the LMI version of the DCF model has specific deficiencies, as detailed in Section VII of this Final Report by both the LTV/VAPD and the Westinghouse paper-test of the model. It is noted here that the Westinghouse version of the DCF model overcomes several of the LMI version's deficiencies.

06. ABILITY OF MODEL TO SATISFY OVERALL PROJECT GOAL

CDEF: There is some disagreement as to whether the Price Waterhouse model is sufficient to satisfy the overall project goal. Price Waterhouse believes it is. Westinghouse believes it is not. LTV/VAPD believes it would need to be integrated with other models to do so. This model is not now necessary at LTV/VAPD.

MFPMM: The MFPMM version used by LTV/VAPD would not by itself be sufficient to satisfy the overall project goal. Without macro incentives, one would require MFPMM + a DCF model + a CBT model at the program or project level. This model is presently not necessary.

DCF(LMI): The discounted cash flow model again caused some disagreement among project team members. Westinghouse believes it is sufficient. Price Waterhouse believes the model is insufficient. LTV/VAPD believes the model is insufficient. The VPC believes the model is insufficient. The model is presently necessary.

08. RECOMMEND (NOT DEVELOP) MODIFICATIONS, IF ANY, TO MODELS

CDEF:

Discussions with LTV personnel indicate the following recommendations:

- Make easier to use - Develop a brief manual which described the generic steps required to implement CDEF (assuming no productivity measurement system is in place).
- Make easier to control - Develop a training course for users of CDEF.
- Make easier to administer - Provide user-oriented documentation and demonstrations for the CDEF software module, ACBG.
- Make easier to obtain descriptive information - Provide actual examples of the costs required from the general ledger.
- Make easier to use in incentives/rewards applications - Document the flow of the information process from data collection to calculation of shared savings.

MFPMM:

- Develop improved output for various audiences.
- Develop an improved tutorial for various audiences with which to explain the model.
- Develop a solution to capacity utilization vs. efficiency issue.
- Continue to investigate improved accuracy and quality of inflation factors, indexing factors, etc.
- Develop better and more accepted linkage to incentive mechanisms.
- Develop macro gainsharing from government to contractor.
- Improve simulation and forecasting routines for model.

DCF(LMI):

- Develop software modifications which would:*

  1) Permit different classes of investment, for depreciation expense calculation purposes.

  2) Require the contractor to separate the benefits accruing to an IMIP project into government vs. commercial proportions.

  3) Accurately reflect the lost profits incurred by a contractor due to additional depreciation expenses caused by an IMIP project.

  4) Recognize that a contractor's initial start-up project expenses are unreimbursable costs.

  5) Compute a DoD/Government rate of return due to an IMIP project.

  6) Perform a larger number of internal calculations such as "profit effect" and "productivity savings reward".

- Develop a User's Manual which not only explains the software (as corrected above) but also provides a detailed set of procedures for submitting and executing an IMIP project proposal.

* In Section VII of this Final Report, see Westinghouse's comparison of the LMI vs. Westinghouse versions, and the LTV/VAPD paper-test of both versions.

## 09. RECOMMEND WHETHER OR NOT TO CONDUCT A FIELD TEST

We believe there is a need for a more systematic and disciplined productivity management effort in the defense industry. Improved measurement and evaluation systems must play a key role in this effort. Measurement and evaluation is complex in this industry and no single model will suffice. Each of the three models tested in this study can, and have, played a significant role in productivity management efforts within the industry. We believe further development of the three models is therefore necessary. Perhaps more importantly, a generic methodology for productivity management efforts within the industry needs to be further developed and communicated. The role that these three models, and others, play in that methodology needs to be understood by a broader audience within the industry if any real impact is to be made.

There is a reasonable consensus among the research team as to how to proceed during Phases IV and V of the overall study. It has been agreed that proceeding with a field test for the CDEF model, as outlined in the original proposal, is not economically feasible without significantly reducing the scope of the application. Since LTV is developing their own version of the DCF/SSA model, field testing that model, per se, does not make sense. The MFPMM would stand to benefit most from a field test as outlined in the proposal.

The general recommendation regarding a continuation of the research is to combine Phases IV & V into a single, 18 month project which would develop and test a comprehensive productivity management implementation guide. The effort would focus on resolving specific developmental needs of the three models via a modified, scaled-down field test at LTV/VAPD. We would additionally, "field test" the methodology, and the models, with representative defense contractors in an intensive workshop setting. A detailed analysis of responses from sampled contractors would be made to assess points of resistance and implementation barriers. A draft implementation guide would be reviewed during these workshops to ascertain the level of industry resistance/acceptance. A final implementation guide would benefit from expanded exposure to other contractors beyond LTV/VAPD and our industrial advisors. The models and methodology would benefit from continued detailed analysis and development with LTV/VAPD to the extent necessary.

B. General Recommendations and Conclusions

Introduction

It is fundamental that the U.S. Government wishes to acquire defense-related products and systems which have, for example, maximum quality (as measured by accuracy, reliability, etc.), minimum cost, and minimum procurement time (from design to production to delivery). In a competitive environment, contractors must strive to meet these governmental objectives but also must meet company objectives of reduced costs, increased profits, etc. if the company is to survive and grow in both the short and long-term. Certain governmental and contractor objectives can be in conflict and thus, government to contractor incentive (gain-sharing) methodologies such as IMIP are viewed as a way to eliminate, or at least substantially reduce, such conflicts of interest.

Conclusions

An overall conclusion from this Phase III study is that contractors need to institute, promote, and maintain a broad-scope, effective productivity management methodology which would represent a "Grand Strategy" for their business unit(s). This methodology should encompass the productivity elements of planning, measurement, evaluation, control, and improvement. A related conclusion is that the Vought Aero Products Division of the LTV Aerospace and Defense Company has developed, instituted, promoted, and is maintaining such an integrated productivity management methodology (development is of course a continuing process).

From the viewpoints of (1) an integrated productivity management methodology, and (2) the accomplishment of all the performance improvement goals of the government and contractors, none of the three models which were "paper-tested" will individually achieve these viewpoints. However, these three models can be combined into an effective productivity management methodology. Individually, each of the models are relatively new and have current developmental problems which need to be, and are being, worked on.

The MFPMM must be modified rather significantly to function in the defense industry environment. LTV has successfully made this conversion and have found the model useful as an integral component of their productivity management methodology. (Some development issues associated with the model still need to be resolved). However, of the three models tested, only the MFPMM actually measures input-output productivity. A possible exception to this statement is that the DCF/SSA model is a productivity measure in that it is an aggregate, end-result profitability measure (capital investment input with annual savings output).

The DCF/SSA model is primarily an analysis tool designed to help management and the government evaluate the merits of selected productivity improvement projects. It is best described as an analysis and decision-making tool for planning and forecasting purposes. However, there are major deficiencies in the software developed by the Logistics Management Institute for model implementation (e.g., see subsection VII.D.2 -Volume II of the Final Report). Neither does a User's Manual exist for the software.

The Price Waterhouse model (CDEF) performs well against the objectives and criteria for which it was designed. The node-tree activity structure (IDEF analysis) can differ significantly from a company's organizational structure and, depending upon the complexity of the organization, may require varying amounts of effort to develop. It is noted, however, that the IMIP Guide 5000-XX.G required that an IDEF-type analysis be performed by a contractor. The CDEF methodology has been successful with certain companies. Nevertheless, LTV has perceived the cost to implement the complete methodology to be high, relative to alternative approaches, such as the development of separate cost center accounting for each Modernization Improvement Project (MIP).

Aside from the evaluation of the three models as productivity measurement and evaluation tools, the research team considered some general aspects of the IMIP program and its related guidelines. The significant conclusions from this consideration are as follows:

1) IMIP guidelines do not provide enough clarity of direction to the contractor for the submission and justification of a Manufacturing Efficiency Project (MEP). LTV has detailed their specific concerns in Subsection VII.D.-Volume II of this Final Report.

2) The impact of an IMIP project on the aggregate costing rates which a contractor uses for government pricing purposes may not be clearly understood by either the contractor or the government. This issue is a particular concern of Westinghouse and suggests further study on this issue is warranted.

3) Variances in operating systems, management styles, pressures and priorities, perceived problems and opportunities, and skilled/competent productivity management personnel will very likely make it difficult to translate and transfer models and methodologies from one company to the next. The issue/problem of translation and effective transfer needs to be thought through very carefully.

The final conclusion of the research team concerns the future Phases IV and V of the overall study. It has been agreed among the research team that proceeding with a field test for the CDEF model, as outlined in the original proposal, is not economically feasible. However, at a significantly reduced scope of application, field testing of the CDEF model is warranted. Since LTV, as well as others, has developed (or is developing) their own version of the DCF/SSA model, field testing of the LMI version of the model is not necessary. However, based on knowledge gained during the Phase III study, some further investigation/analysis of the DCF/SSA model is warranted. Since LTV is currently using a modified version of the MFPMM, for macro productivity measurement, this model is also judged an appropriate model for further field-testing, particularly in regards to macro incentive methodology.

In summary, each of the three models tested in this Phase III study can, and have, played a significant role in productivity management efforts within the defense industry. It is therefore believed that further development of the three models is necessary. Perhaps more importantly, a generic methodology for productivity management efforts within the industry needs to be further developed and communicated. The role that these three models play in that methodology needs to be understood by a broader audience within the industry if any real impact is to be made.

## Recommendations

The primary recommendation to be made concerns the continuation of the research in Phases IV, V of the overall study. It is the research team's recommendation that these two phases be combined into a single, eighteen-month project which would conduct a modified field test of the models and develop a productivity management Implementation Guide. The effort would focus on resolving specific development needs of the three models via a modified, scaled-down field test at LTV/VAPD. Additionally, the methodology and the models would be field-tested with other defense contractors in an intensive workshop setting. A detailed analysis of responses from sampled contractors would be made to assess points of resistance and implementation barriers. A draft implementation guide would be reviewed during these workshops to ascertain the level of industry resistance/acceptance. A final implementation guide would benefit from expanded exposure to other contractors beyond LTV/VAPD and our industrial advisors. The models and methodology would benefit from continued detailed analysis and development with LTV/VAPD to the extent necessary.

The development of the Implementation Guide, as discussed above, should accomplish the following specific recommendations:

1) Modify the Multi-Factor Productivity Measurement Model to more appropriately reflect the defense contractor/government environment.

2) Survey, through a designed workshop environment, a representative cross-section of defense contractors to determine the viability of instituting a productivity planning, measurement, evaluation, control, and improvement methodology.

Finally, the recommendations to follow are considered <u>outside-the-scope</u> of the combined Phases IV and V project discussed above:

a) The LMI software version of the DCF/SSA model should be modified to correct the deficiencies noted in Section VII, Volume II of this Final Report. Further, a more comprehensive User's Manual should be developed to accompany the software with an IMIP project fully illustrated in the User's Manual.

b) An Implementation Guide needs to be developed to fully describe the methodology and criteria requirements to use the DCF/SSA model for IMIP purposes.

c) Develop a more definitive set of guidelines for submitting and justifying a Manufacturing Efficiency Project (MEP).

d) Investigate and define a more precise set of specifications required by DoD for cost-tracking purposes.

e) Develop a comprehensive treatise on the impact of aggregate vs. project-related cost accounting rates and factors on IMIP-related projects.

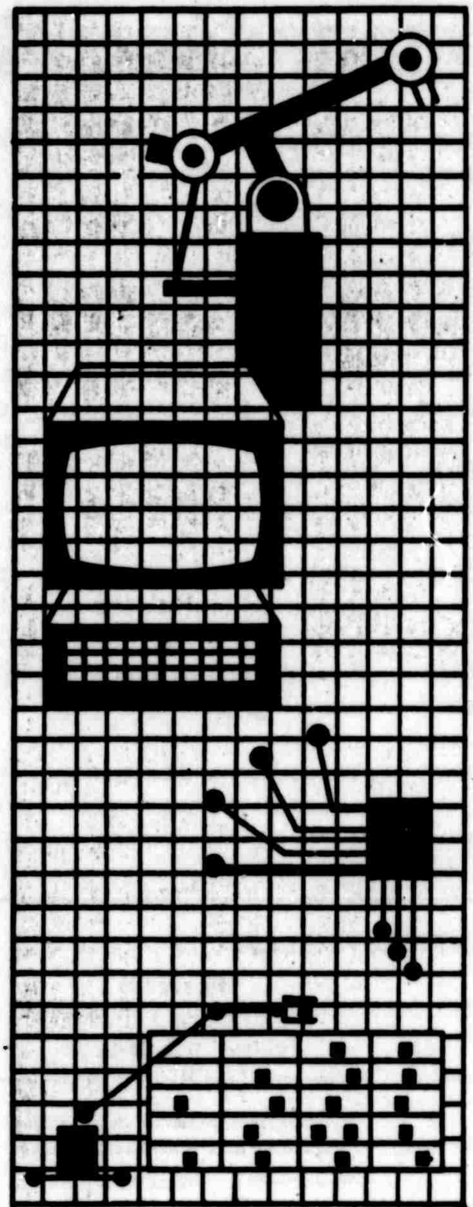
## APPENDIX A

Detailed Description of Each Model

1. CDEF
2. DCF/SSA
3. MFPMM
4. LTV Integrated Approach

# APPENDIX A.1

## Description of Price Waterhouse CDEF Methodology



# An Approach for Selecting/Managing Factory Automation Projects

**Price Waterhouse**

*Management Consulting Services*
*Computer Integrated Manufacturing*

# The relationship between technology and cost management

Many manufacturing companies, seeking to improve their productivity, are turning to advanced computer-based technologies for cost containment solutions. As they do this, the two primary challenges faced are (1) the justification and (2) the management of the selected technology-based environment. They are finding that productivity improvements are not an *automatic* result of the installation of new technologies. They are finding instead that managing a technology-based manufacturing environment is substantially different from managing a corresponding labor-based environment.

The fact that many companies have attained less than the expected results is usually attributed to a number of problems, including:

- Estimated benefits and costs are found to be unrealistic and incomplete. For example, one company's accountants forgot to estimate a flexible machining system's impact on maintenance costs;
- Difficulties in quantifying and tracking costs and benefits, particularly as they relate to the economics of integration and system support needs; and
- A lack of top management commitment, as evidenced by emphasis on short-term fixes and immediate return on investment, rather than long-term goals.

Companies which are successful implementing new technologies and moving from a labor-based to a technology based environment, have been found to use a structured master plan. This type of plan focuses attention on the key variables or "drivers" which impact overall cost and performance, i.e., key success factors (KSF). The purpose of this series of articles is to analyze the fundamental and basic issues of technology management and to describe an approach which can be used to improve your chances of success in implementing manufacturing technologies.

**Productivity and efficiency**

Manufacturing excellence is on the minds of many contem-

**FIGURE 1. TECHNOLOGY MANAGEMENT MASTER PLAN**

**Phase I: "As Is" Factory Analysis**

- Organize project team and workplan.
- Develop "As Is" factory model.
- Conduct needs analysis of existing manufacturing processes and systems.
- Conduct needs analysis of "future" manufacturing processes based on company strategic plans and perceived movements within the marketplace.
- Prioritize improvement areas.
- Prepare conceptual "To Be" designs and perform integration analysis.
- Validate cost-benefit analysis and cost-benefit tracking techniques.
- Establish Phase II/III strategy.
- Document project economics.
- Obtain management approval to proceed with Phase II.

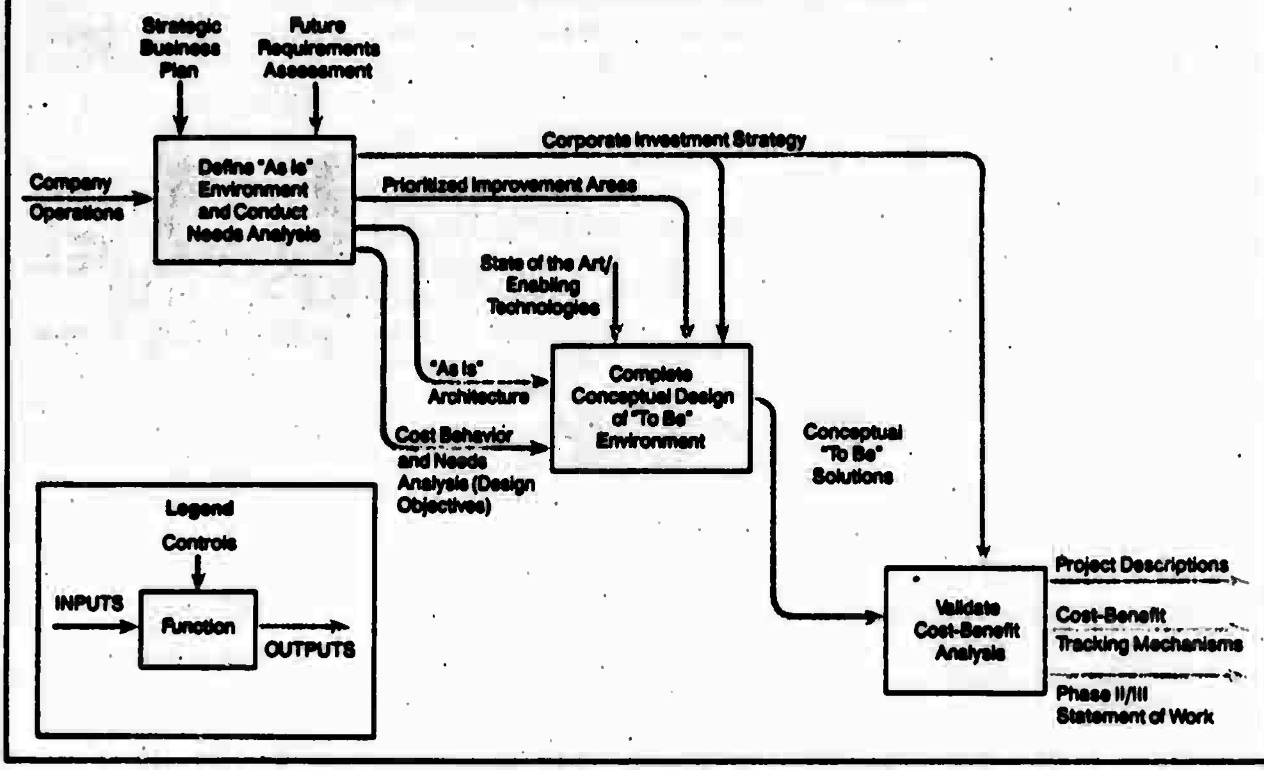
**Phase II: Detailed Design of "To Be" Configuration**

- Complete detailed design and analysis of primary and support technologies.
- Conduct factory integration analysis.
- Prepare requirements specification.
- Issue RFP and evaluate vendor offerings.
- Prototype and demonstrate technology(s).
- Finalize design and vendor selection.
- Plan Phase III implementation.
- Re-validate cost-benefit analysis and tracking.
- Obtain management approval to proceed with Phase III.

**Phase III: Implementation and Follow-Up Verification**

- Complete implementation prerequisites and detailed work tasks.
- Develop training program.
- Install hardware and software.
- Establish appropriate physical and system control points.
- Conduct phased implementation.
- Enact required organizational and administrative changes.
- Conduct milestone post-implementation review.
- Maintain technology master plan.

**FIGURE 2: PHASE I EXECUTION STRATEGY**




porary executives. Beyond product quality and customer service considerations, manufacturing excellence is dependent upon the effective selection and management of the production resources. *Productivity* and *efficiency* are now watchwords of every manufacturing company.

Productivity generally is increased by producing a greater volume of outputs from an unchanged volume of inputs. Efficiency is increased by producing the same output using less input. Continually generating productivity and efficiency improvements is therefore the key ingredient of manufacturing excellence. Thus, to attain excellence, many manufacturing companies are increasing their interest in the introduction of new technologies to improve cost, schedule and quality management. For this reason, technology management is a critical strategic issue in most modern manufacturing companies.

The reason for introducing a new technology is to substitute one cost factor of production for another: for example, installing a robot to replace a manual operation. In addition to favorable cost considerations with this substitution, management must be assured of equal or improved levels of quality and throughput.

As simple as this concept may seem, it brings most managers face-to-face with three potentially significant issues which, if not properly resolved, can deter the successful implementation of the technologies:

1. What improvement opportunities will provide the greatest potential benefit? Which area should I invest in first?

2. How do I quantify the anticipated benefits and track the actual benefits?

3. What are the supporting management system requirements?

**Why cost management is important**

Conducting a technology improvement study is a significant and demanding task. The current nature of the manufacturing environment introduces a number of new constraints on the ability of traditional cost accounting systems to quantify and track increased productivity resulting from technology improvements. These constraints are:

- Product life cycles are becoming shorter while the rate of engineering changes increases.
- Production processes are becoming less reliant on direct labor as the primary factor in production control.
- The introduction of new technologies rarely replaces existing methods on a one-for-one basis.

All of these factors, and more, contribute to the difficulty in establishing a fixed baseline from which to measure costs and productivity.

In order for technology improvement programs to be successful, a comprehensive and structured approach is required. Equally important is the need for effective cost management methodologies (or tools) to:

• Identify those functional manufacturing areas which represent the greatest potential for cost and productivity improvements;

• Analyze those cost-behavior patterns and productivity "drivers" which have a significant impact on cost; and

• Quantify and track productivity improvement measurements.

**Expanding the focus of cost management**

Traditionally, cost accounting has been associated with the accumulation of historical data on material, labor and related overhead costs for valuing inventory and costs of goods sold. The variances that are developed are usually financial and rarely show operational productivity trends (i.e., planned to actual variances of the key success factors of the manufacturing function). Cost accounting has often been left to the accountants as a historical record keeping system. It generally has not been an integrated and dynamic part of the operational management planning, control and measurement process.

To be effective, cost management should be the primary barometer of the effectiveness and efficiency of the various operating functions of a company. Many managers have expressed a desire for comprehensive measures of productivity and improved cost management systems as a basis for awareness and action. Recently, several specific needs have caused managers to turn their attention to the area of expanded cost management, including the need for:

• *More timely knowledge of actual product costs.* In many cases, this may require that controllable costs be separated from those which are relatively fixed over a fairly broad range of production volumes. This information can help managers perform "basic" tasks such as: make-versus-buy decisions; timely identification of variances at the operational level so that corrective actions can be taken; and, determining if least-cost manufacturing processes are currently being used.

• *Better knowledge of individual product costs.* This is a strategic matter that companies must address to maintain their competitive position, particularly as it relates to product-line management and product pricing.

• *Improved identification, justification, development and implementation of new technology applications to better plan and control costs, schedules and quality.* Traditional project management techniques are not always satisfactory for:

1. Needs analysis (i.e., selecting those alternatives which represent the greatest potential benefit;
2. Cost-benefit analysis, which identifies all critical manufacturing elements (functions and activities) and their cost and benefit considerations;
3. Formal risk management (i.e., maximizing the anticipated benefits); and
4. Tracking resulting costs and benefits.

*It (cost accounting) generally has not been an integrated and dynamic part of the operational management planning, control and measurement process.*

It is this last aspect of improved cost management which strikes at the heart of technology management. The development of a truly effective technology management program depends on a sound approach to cost management which is integrated within the framework and strategy of the overall manufacturing effort. These three articles are intended to articulate the importance of cost information to define performance, set priorities, and provide the means to establish specific design objectives and manage performance for the new technology-based environment.

**State-of-the-art thinking**

Rising concern over such problems as declining productivity, increased competition, and potentially obsolete capacity has encouraged the introduction of factory of future concepts such as robotics, automated material handling, computer-assisted design, etc. Those companies which desire to remain successful must use state-of-the-art planning, as well as state-of-the-art manufacturing technologies. Proceeding without a technology master plan can be a fatal mistake.

From the outset of technology improvement, there should be a recognized need for a plan that will provide guidance that is consistent with company goals and objectives. In order to assure a strategic and systematic approach, the following concepts should be part of the overall planning and technology-improvement effort:

• Preparation of a master plan which encompasses considerably more from a strategic perspective than just "making the lathe turn faster;"

• Preparation of a master plan which recognizes the importance of conducting a formal needs

## About Price Waterhouse and the authors

One of the Big Eight firms in the accounting establishment, Price Waterhouse has 87 offices and employs more than 7,000 people in the U.S. The company offers a complete range of services: auditing, accounting, tax and Management Advisory Services (MAS). MAS includes disciplines such as:

- Organizational management,
- Financial and budgetary planning and control,
- Manufacturing and operations management,
- Electrical data processing and programming,
- Management information and control systems,
- Operations research,
- Management sciences, and industrial engineering,

**Concerning the authors:**

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*William T. Muir* (center) is a Price Waterhouse partner and lead technical specialist in the area of operations and manufacturing management. He has 18 years of experience in the areas of cost accounting and performance measurement, materials and production management systems, and distribution. Muir is an industrial engineer and has an MBA in Quantitative Analysis. He is a senior member of AIIE and an APICS practitioner.

*Lawrence T. Michaels* (right) is a Price Waterhouse senior manager and a lead specialist in the area of manufacturing systems. His experience includes 12 years of design, implementation and management of comprehensive management systems and advanced technology applications (MRP and CAD/CAM/CIM). Michaels has an MBA in management. He is a certified practitioner of IMMS and APICS.

analysis and conceptual design prior to proceeding with detailed design and implementation;

- Establishment of a multi-disciplined project team and a project scope which encompasses all aspects of company operations; and
- Utilization of cost-benefit analysis tools which focus on key success factors, integrated performance measurement, and the concept of cost "driver" management.

**The first step:**
**a realistic master plan**

It has been well documented that many companies proceed with technology improvements without first conducting a strategic needs analysis and comprehensive conceptual design. The purpose of the needs analysis and conceptual design activities is to identify and rank-prioritize improvement opportunities and to develop the specific objectives which guide the implementation tasks. The principal benefits to be realized from this approach include a high level of management commitment and understanding of:

- Company needs in terms of which areas represent the greatest potential for improvement;
- The importance of defining performance before attempting to measure and control it; and
- The crucial trade-offs associated with manufacturing function cost displacement, i.e., assurance that the solution is complete and will focus on real opportunities, provide the anticipated results and not increase overall costs.

It is important that the master plan reflects substance as well as form. The overall strategy and structure of the plan must be well understood by all participants and it should foster user sponsorship (genuine ownership) of the proposed solutions. Figures 1 and 2 illustrate the basic elements of a technology master plan that have been used successfully by several companies.

**The second step:**
**the right people and skills**

Technology management success requires an investment in people, as well as technology. The investment in people is best exemplified by:

- The use of multi-disciplined project teams; and
- Bringing the necessary technical skills and experience to the project team.

Unfortunately, the use of multi-disciplined project teams is not as common a practice as some may think. The use of multi-disciplinary teams will ensure a proper and complete assessment of improvement opportunities, a thorough understanding of critical issues and potential barriers, and will contribute to user commitment to company (rather than parochial) solutions. This approach will also contribute to an understanding of the strategic importance of the work effort.

The commitment to bring all the necessary skills and experience to the project may represent a change in philosophy from prior project management efforts. The implications of this are four-fold.

First, it is a recognition of the importance of the project by rejecting the notion that a person is too valuable to be assigned to it (i.e., the best people are assigned to the project if it is a truly important project).

Second, it may represent the realistic assessment that the company presently lacks the resources, technical expertise and prior experience necessary to achieve the desired results (i.e., the need to use external assistance).

Third, by accepting a different approach from prior efforts, there is a rejection of the attitude that the company is different from others which have been successful.

Finally, it may be necessary to also seek outside assistance to ensure objectivity, as well as the use of practical and proven project management tools and mechanisms so as to produce timely and cost-effective results.

The decision to hire specialized skills or to use outside assistance should be viewed as management's commitment to the importance of the solution, rather than with skepticism or as a political move. Likewise, although some companies have established a multi-disciplined team responsible for these programs, the availability of these resources does not mitigate the need for direct involvement by the operations or departments who will use the solution. Many successful companies have used specialists to provide "technology transfer" in terms of education and training in the use of project management tools; but the ultimate success of any technology improvement project depends on the level of commitment made to it by its users.

**The third step: a better mousetrap**

The final key ingredient for success in technology management is a cost-benefit analysis and tracking methodology which addresses key success factors, provides integrated and comprehensive measures of performance, and focuses on "cost drivers." The key success factors approach is a technique for integrating the factors of the "As Is" and "To Be" cost baselines with the strategic business plan.

The use of this technique will enable the project team to evaluate the current mix of resources (the "As Is" cost baselines) in a manner consistent with top management's view of the future (the "To Be" cost baseline). For example, this approach can be used to emphasize operations which are energy intensive, use a strategically scarce material, or are not suitable for meeting future market and product requirements.

A comprehensive manufacturing cost and productivity model also needs to be developed in order to define the "As Is" and "To Be" operating baseline for each functional area to be improved. This model should include specific dimensions of performance, define all relevant cost elements, and identify those independent variables or "drivers" which directly impact cost.

The term "cost driver" is an important concept which needs to be addressed throughout the entire technology improvement program. In many cases, users manage the variables of production which impact costs, rather than directly managing the cost elements themselves. For example, lead time is a cost driver of work-in-process inventory carrying costs; machine speed and throughput efficiency are drivers which affect production costs; and so on. The identification of cost behavior patterns (such as high scrap/rework) and the "drivers" which impact those cost-behavior patterns will provide specific objectives for the conceptual design activity. It is the identification of cost-behavior patterns and "drivers" which represent the essence of the needs analysis process. This ingredient for success will be described further in the next two articles.

**Potential benefits**

Based upon many successful experiences relating to integrating cost management within the technology management process, companies which implement the concepts and strategy described should herein receive the following benefits:

- Increased recognition of significant product cost containment/reduction opportunities;
- More effective analysis and monitoring of the costs and benefits of technology improvement projects;
- Technology improvement solutions which focus on the key success factors and cost "drivers" of the manufacturing function(s), and address the overall goals of the company; and
- Improved control over manageable production costs.

**Conclusion**

A number of companies have adopted the improved approach to technology management as suggested by this article. In particular, many aerospace defense contractors have applied these concepts to a wide range of manufacturing environments and are now realizing some of the potential benefits.

The many challenges facing American companies today indicate that technology management is a critical strategic issue. Those companies which fail to focus on the demands and opportunities presented by technology improvement are risking their continued profitability and long-term survival.

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# Improving technology cost-benefit analysis

By Lawrence T. Michaels, William T. Muir and Robert G. Eiler
Price Waterhouse

Manufacturing excellence is dependent on the effective selection and management of production resources. Companies seeking to increase productivity through factory automation are presented with two major challenges: the justification and the management of a technology-based environment.

In order to address these challenges, many corporate managements are taking a hard look at their cost management systems. These managers are concluding that their cost accounting and performance measurement practices are inadequate. They are realizing that direct-labor-based cost accounting systems and traditional financial techniques are not adequate tools to quantify and track productivity improvements for advanced manufacturing technologies.

Successful companies need to use state-of-the-art thinking as well as state-of-the-art technology. The first article in this series described three success factors for sound technology management:

- Developing a realistic and proper master plan to guide the overall technology modernization work effort;
- Bringing the right people and skills to the project team; and
- Using effective cost-benefit analysis and tracking techniques.

We have observed that technology management "winners" are using expanded cost management concepts. The benefits resulting from this are:

(1) Identifying those areas which offer the greatest improvement potential;

(2) Improving the cost justification process; and

(3) Defining better measures of performance to manage the new environment.

The potential risks of ineffective technology management are more than just declining rates of productivity growth. "Nonwinners" run the risk of declining profitability and are jeopardizing their long-term survival.

**Fundamental problems**

Several fundamental problems face many manufacturing companies. Each of these problems points out the need for an improved approach to cost management which is formally integrated within the technology modernization process. The four major problems can be defined as follows:

*Many cost accounting systems no longer reflect the manufacturing process.* In many instances, the cost system was developed years ago and has not evolved or kept pace with changes in the production environment. Because of the declining direct labor pool, measured direct labor may no longer be the appropriate basis for allocating or assigning fixed indirect costs (overhead) to products. The problem is worsened because many systems ignore certain process and product costs — such as material handling and the expenses associated with maintaining inventory levels.

*Cost patterns have changed.* Manufacturing overhead continues to grow; for many companies it is now 400 to 500 percent of direct labor. For this reason, cost control efforts need to be redirected with added focus placed on indirect costs. Costs such as maintenance, quality control and material handling can and should be evaluated and controlled on a direct basis. The assumption that a reduction in measured direct labor will produce a corresponding reduction in indirect costs often has been proved wrong.

*Direct labor is no longer the driver for production control.* In many companies, performance measurement does not mirror the production process. Traditional cost management systems are not well-integrated with other manufacturing information reporting. These management systems hinder performance-based manufacturing management. This problem causes inadequate understanding of: (1) those variables or drivers which impact production cost and performance (key success factors); and (2) how these drivers affect actual costs.

*Traditional financial techniques are inappropriate for technology planning.* Payback and return on investment calculations only evaluate previously identified projects; they do not identify potential improvements. These techniques also only assess financial feasibility (they tend to ignore the useability of the technology — i.e., the human factors issue).

As a result of these fundamental problems, many companies are experiencing difficulties in:

- Defining and maintaining operating baselines (i.e., assessing the cost impact of product/production mix changes);
- Explaining why actual costs deviate from the plan (effective variance analysis); and
- Most importantly, developing cost behavior patterns to define specific objectives and provide focus to the technology modernization effort.

These problems and resulting difficulties are causing corporate executives to rethink their approach to cost management.

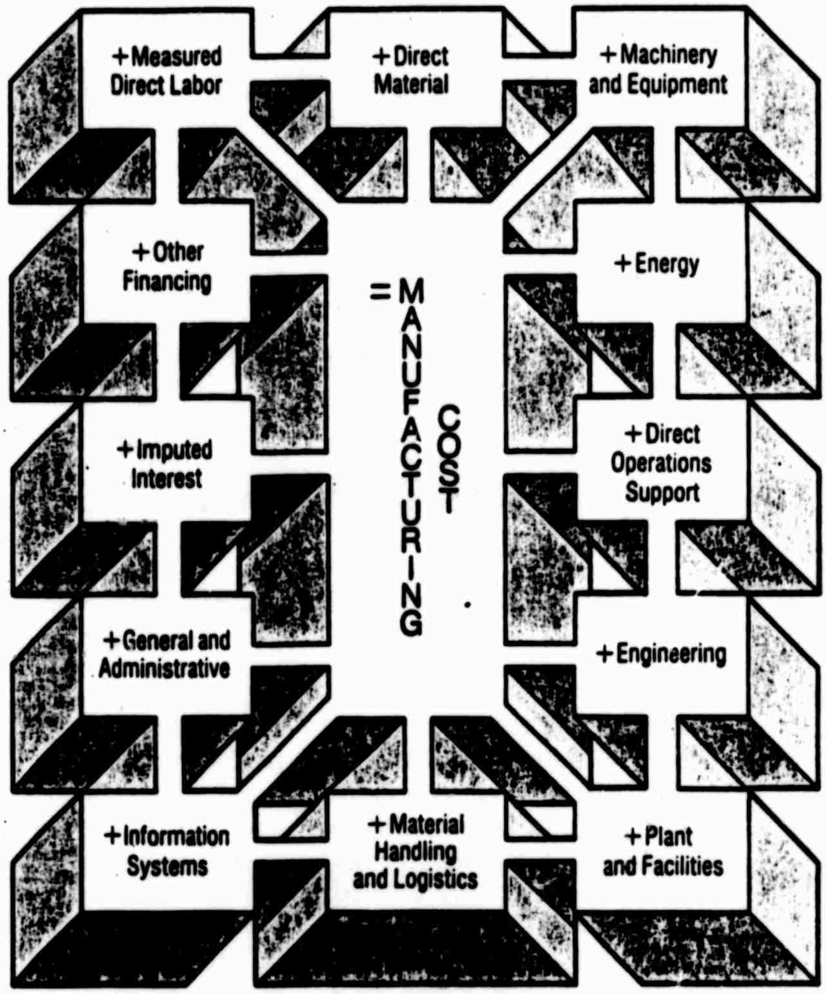


**Figure A: Manufacturing Cost Model**

They have expanded the focus of cost management and developed improved cost-benefit analysis procedures. As a result, their companies have been able to realize significant benefits which have been promised by proponents of technology modernization.

## A success formula

Technology management winners have come to learn that cost-benefit analysis is a key work task. There are several reasons why enhanced cost-benefit analysis is especially important.

First, there may be confidence that the technology works, but uncertainty regarding whether the economics are right for your company. Because of prior failures or limited success (in terms of resulting savings), most projects must be cost justified in order to obtain management approval to proceed.

Second, operating budget constraints cause factory automation projects to compete with other requests for funds. For this reason, there is a critical need to identify those factory areas which represent the greatest opportunity for cost reduction. Third, continued management confidence and investment in new technology requires that all costs and benefits be tracked. Successful projects are those which provide the anticipated results (i.e., reduce overall costs). Those projects which merely displace costs (substitute one element of cost for another) can cause resistance towards further investments in new technology. The remainder of this article will describe a general cost-benefit approach which many companies are now using when investing in factory automation.

**Cost-benefit analysis work steps**

● *Step 1: Develop a model of all factory functions.* Many companies use segments of the $IDEF_0$ (Integrated Computer Assisted Manufacturing Definition) modeling approach to document the "As Is" factory environment. $IDEF_0$ uses a top-down structure to describe manufacturing and engineering work activities in terms of functions. A top-down structure for a factory is similar to a bill of material diagram for a product. This functional approach offers two advantages over a product/process viewpoint:

(1) Because new technologies rarely replace existing processes on a one-for-one basis, a functional viewpoint enables similar (or closely related) activities to be analyzed together; and

(2) A complete analysis of potential solutions requires that all support systems, controls and interfaces be identified and evaluated. Each level of the factory model is further decomposed into lower levels until the subfunction is small enough to be analyzed.

The result of this work step is a model of the factory which describes inputs, outputs, controls, interfaces and mechanisms (labor, machines, etc.) for each function.

● *Step 2: Quantify manufacturing costs.* The manufacturing costs should next be identified for each function of the factory model. Total manufacturing costs include more than direct material and measured labor standards.

Figure A provides a high-level definition of overall manufacturing costs. Each of the major cost elements shown in Figure A is consolidated or subdivided into additional levels of detail, depending on the magnitude of the costs. This step is completed after all costs have been allocated to the lowest level of the functional model. Care must be taken in allocating cost elements to the detail levels of the model in order that complete and accurate cost definitions can be prepared. That is, a function's cost should not be over- or understated, and the total cost of all functions should equal overall manufacturing costs.

The result of this work step is a cost baseline which identifies the costs for each function in the factory model.

● *Step 3: Develop criteria to rank/prioritize factory functions.* The purpose of this work step is to develop a ranking criteria to prioritize the conceptual design activity. The opportunity for improvement is greatest for functions which have low performance and high costs. In order to complete this type of ranking, it is first necessary to define dimensions of performance. The ranking criteria (normally a computer-based model) should identify these specific measures of performance. As described in the previous article, the key success factor approach should be used to integrate the dimensions of performance with the cost baseline and strategic business plan. Examples of key success factors include:

● Manufacturing throughput (lead time),

● Machine utilization,

● Direct labor productivity,

● Ability to meet deadlines, and

● Quality (scrap and rework rates).

The result of this work step is a way (formula) to rank/prioritize the improvement potential of the factory functions.

● *Step 4: Conduct an effec-*

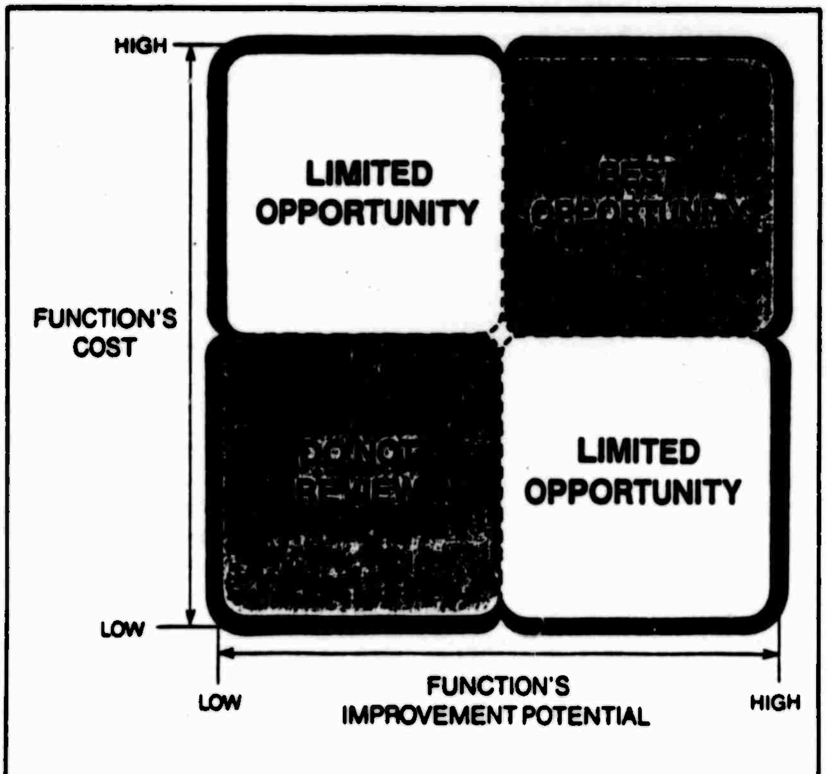


**Figure B: Rank/Prioritizing Improvement Opportunities**

*tiveness review.* Each function is next analyzed to determine how effectively work is being performed. This analysis is based on the performance measures (or key success factors) identified in Step 3. High operating costs should not be the only criteria for selecting potential projects. Some functions with high costs may also have high performance, and therefore present little opportunity for improvement. The purpose of this step is to define "As Is" performance so that each function's improvement potential can be judged.

The results of the effectiveness review are then matched with the cost baseline information, using the ranking criteria. This will produce a ranked listing of improvement opportunities (Figure B). Those functions with high cost/low performance will appear first on the list. Those functions with either high cost/high performance or low cost/low performance will be listed next. At the bottom of the ranked listing will be functions with low cost/high performance, because they offer the least opportunity for improvement.

• *Step 5: Identify improvement alternatives.* Technology-based improvement alternatives are next screened (or combined) for each high improvement potential area. The cost behavior patterns (step 2) and performance measures (step 4) should be used to guide the conceptual design activity. Cost behavior patterns and performance measures provide a specific set of objectives for completing the conceptual design activity. This approach will ensure that the proposed solutions will focus on cost reduction/containment opportunities and are consistent with company goals.

The result of this work step is a conceptual design of the "To Be" function. The conceptual design should describe the new technology in terms of scope, intended use, and how problems of the "As Is" environment will be resolved.

• *Step 6: Develop "To Be" cost baseline for each improvement alternative.* Project development and implementaion costs and expected benefits are next developed for each improvement alternative. The documentation of expected benefits should analyze each element in the cost baseline. This will result in an estimate of the "To Be" for each cost element (functional cost changes) as well as development and implementation costs.

The results of this work step is a preliminary assessment of the "To Be" cost baseline and an estimate of one-time project costs.

• *Step 7: Analyze project risks.* Many times, project personnel will develop over-optimistic projections of potential benefits. This type of projection is often known as the best-case scenario. Project risks must be analyzed to ensure that potential benefits will not be overstated. Personnel in departments involved in the project can be very helpful in assessing potential risks. Their involvement will also contribute to project-user acceptance and sponsorship of the proposed solution. Formal meetings with key company personnel (department foremen, maintenance superintendent, quality control representative, MIS, cost accounting, etc.) should be held to assess potential risks. The purpose of this type of meeting is to identify the most sensitive assumptions about the "To Be" conceptual design and develop "worst" and "expected" case scenarios (Figure C). A secondary, but equally important objective, is to develop a formal risk management program — understanding of "what could go wrong" and what must happen to maximize potential benefits.

The result of this work step is a conceptual design which reflects potential risks and planned actions to maximize results and track the expected benefits.

• *Step 8: Prepare conceptual design cost-benefit statements.* Based on the results of the previous step, final cost-benefit analysis statements can be prepared for each improvement alternative. In some instances, it will be appropriate to prepare several cost-benefit statements to reflect the agreed upon best/worst/expected case scenarios. The specific data for each cost consideration can be summarized or detailed, depending on the magnitude of cost-savings and the availability of information.

It is recommended that all key

## About the series

The introduction of state-of-the-art technologies into the manufacturing environment will not, in itself, necessarily improve productivity or help contain costs. Success will only be achieved by making sure that improved operating and financial management concepts support the identification, analysis and introduction of new technologies and their revised cost-behavior patterns.

The first article in this three-part series discussed the relationship between manufacturing technology and cost management. The purpose of this article is to describe the relationship of cost-benefit analysis and performance-based management concepts as they relate to technology modernization. The next article will focus on technology cost-benefit tracking.

— *The authors*

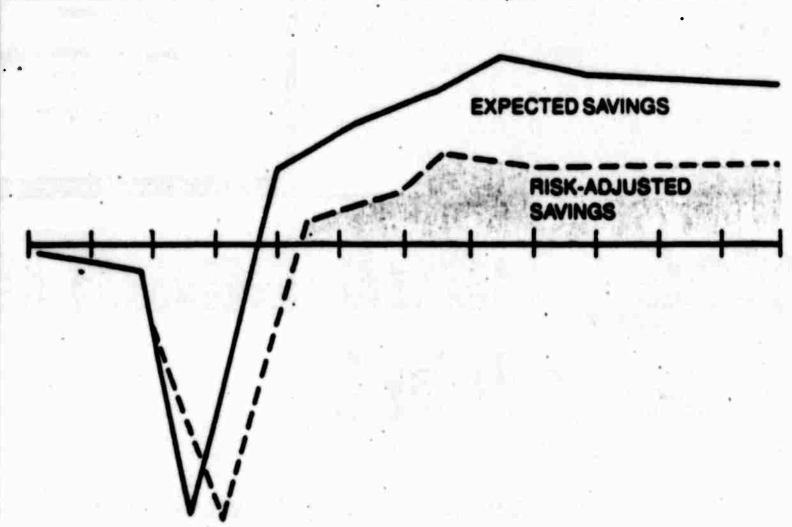

Figure C: Analyzing Project Risks, Best/Worst/Expected Case Scenario

assumptions regarding the cost-benefit analysis be documented. This information is important and should be validated during detailed design/implementation and benefits tracking activities. The validation of project assumptions will be discussed in the next article. The major categories of information which should be included in the cost-benefit statement are:

- Development costs,
- Implementation costs and strategy,
- "To Be" cost baseline,
- Benefits and assumptions, and
- Cost-benefit tracking mechanisms.

The result of this work step is a cost-benefit statement of each technology improvement alternative.

- *Step 9: Determine comprehensive time-phased project economics.* At this last step of the process, the results are turned over to the accounting department. The information which was developed and refined in the previous steps is used to prepare return on investment projections for each alternative. Depending on company operating standards, this normally includes a before- and after-tax assessment of:

- Payback (break even point),
- Investment tax credit and depreciation schedules,
- Savings/investment ratios, and
- Return on investment.

The result of this last work step is a return on investment analysis for each technology improvement alternative. Those projects which meet or exceed minimum return requirements can then be forwarded to top management for final review and approval.

**Potential benefits**

The work steps previously described have been applied successfully in a wide range of manufacturing environments. They have been proven workable for discrete fabrication and assembly and batch process-flow manufacturers. Based on many successful experiences, companies which implement these improved cost-benefit analysis concepts should realize the following benefits:

- Identification of high cost/low performance functions which usually represent the greatest opportunity for improvement;
- Conceptual design activities which use cost behavior patterns and defined standards of performance as objectives for screening potential improvement alternatives. (The identification of key success factors will improve the likelihood of success.);
- Comprehensive solutions which provide a realistic assessment of potential benefits and management actions necessary to maximize the results (formal risk management program); and
- Project-user understanding of the benefits expected and how to manage the new technology environment.

**Conclusion**

The objective of this article was to explain how to improve the needs analysis and conceptual design activities associated with technology modernization. An effective cost-benefit analysis approach is a critical prerequisite for successful implementation of the automated factory. Technical knowledge alone will not be sufficient for planning the future. You will experience two changes when moving from the "As Is" to the "To Be" factory environment. The first change will be the technology base used to design and manufacture your product. The second area of change will deal with management practices and support systems. Those companies which introduce technology must anticipate changes in performance measurements, cost management and data collection activities to support the new manufacturing environment. Technology cannot manage itself. This series of articles offers guidelines for managing the new manufacturing environment.

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# Technology cost-benefit tracking


By Lawrence T. Michaels, William T. Muir and Robert G. Eiler
Price Waterhouse


Management needs a new set of rules for justifying and managing factory automation. High technology processes like flexible machining systems cannot be justified, planned and controlled under the same set of rules as labor-based operations. The introduction of state-of-the-art manufacturing and engineering technologies will not always, in and of themselves, improve productivity or help contain costs.

If the potential of a new technology is to be realized, then management practices must also change as advanced manufacturing methods are selected and introduced. More specifically, measurements of cost and performance need to be improved in many companies to help manage the automated facatory environment. This article will present a successful cost-benefit tracking model applicable to many companies in a wide range of manufacturing environments.

### Why technology cost-benefit tracking is important

Cost-benefit tracking is the reporting process used to monitor and control the manufacturing environment *after* the implementation of new process or information technology. Careful consideration should be given to cost-benefit tracking activities. Otherwise, you may run the risk of expending significant time and resources on a new technology only to find that things are not much better than they were before. The challenge to forward-looking managers is to pay careful attention to the cost-benefit tracking process, in addition to selecting the new technology to be employed. This attention will provide three significant benefits:

- Cost-benefit tracking is the essence of a formal risk management program (i.e., identifying what factors are most critical to the operation so as to manage and maximize potential benefits).
- When properly implemented, cost-benefit tracking becomes the means for performance-based management (i.e., management focus and attention to those key success fac-

## About the series

Significant benefits have been promised by the proponents of technology modernization. "Winners" have recognized the strategic importance of Technology Management. In doing so, these companies have found that many management practices and support systems need to be improved if the anticipated benefits of technology are to be realized.

The purpose of this three-part article has been to provide guidance for the technology management process. The first two articles discussed the relationship between technology and cost management, presented an overall technology master plan, described cost-benefit analysis during project justification and outlined performance-based management concepts. This third article will explain the scope and importance of cost-benefit tracking and describe the basic work steps.

—*The authors*

tors or "drivers" which affect overall cost and productivity levels).

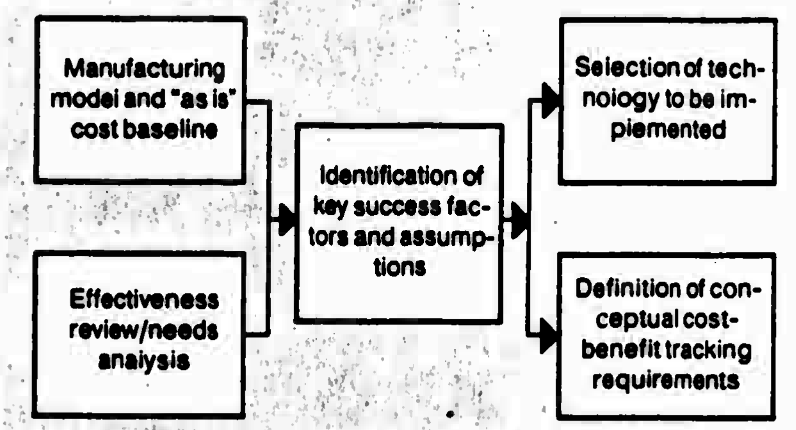
- Confirmation of anticipated benefits will promote management commitment to subsequent investments in process or automation programs.

### Technology cost behavior patterns

Many companies have failed to recognize that advanced manufacturing technologies such as robotics and automated material handling systems have different cost behavior patterns than traditional machining centers. Advanced manufacturing technologies usually require fewer direct labor hours and substantially more support services (engineering and maintenance). The assumption that a reduction of measured direct labor will produce a corresponding reduction of indirect costs has all too often been proved wrong. Limiting advanced technology cost-benefits tracking to only one or two elements of cost (e.g., direct labor and direct material) can create "blind spots" regarding the overall cost profile, and bring about less-than-anticipated overall results.

The cost of factory automation includes more than just the equipment itself. Automated manufacturing processes require significant amounts of other costs such as maintenance, engineering and data processing support activities. The cost of these specialized skills and services may equal or exceed the cost of the device. For this reason, these costly service activities should be monitored in a manner similar to other more direct production activities. In many instances, there will be a direct relationship between machine hours and the system's operating support costs.

**Figure 1. Integration of cost-benefit analysis and cost-benefit tracking**




If an FMS requires the equivalent of a full time industrial engineer to maintain it, this cost factor should be included in the per-unit cost calculation. Many support activities can and should be monitored and controlled in a manner similar to other value-added manufacturing resources.

### Managing the automated factory environment

Technology cost-benefit tracking is, in reality, a recognition that the automated factory requires a change in management practices. Technology cannot manage itself. The techniques and information systems used to manage the "As Is" environment may be inadequate for the "To Be" technology-based factory. Managers will be forced to give greater consideration to the potential impact of a new process technology on both direct manufacturing operations and support services. These considerations include:

- Material handling, quality control and maintenance,
- Industrial engineering support,
- Inventory management and production planning,
- Cost accounting, and
- Computer resources and systems (to support all of the above).

Success will require three basic changes in the management practices of many companies. The first deals with broadening or expanding traditional performance and cost-benefit tracking procedures. Advanced manufacturing technologies will have different development and operating costs than traditional production processes. The amount of engineering development and support is usually greater. Maintenance, computer-resources and production control costs will also change as you move from the "As Is" to the "To Be" environment. On the other side of the coin, this changing technology will produce corresponding benefits which can be quantified and monitored:

- Increased flexibility in the choice of raw material grades;
- Reduced set-up time and improved overall throughput via automated material handling and dynamic dispatching to reduce queue times;
- Improved quality, resulting in reduced scrap, rework and inspection costs;
- Increased flexibility and ca-

pacity in terms of the number, lot size and volume of parts that can be processed; and

- Automated monitoring of machine activities and tolerance specifications, which can lower machine operator costs and also produce higher quality parts.

The second management change deals with the classification and control of many cost factors traditionally considered to be indirect or fixed (overhead). The availability and accuracy of actual data should improve as new process technologies are implemented. With the increased availability and accuracy of shop-floor data, many costs which previously have been considered fixed can be evaluated and managed in a direct manner. This will require moving from a labor-based to a machine/process cycle production control and accounting approach. This change will provide greater visibility and control of the factors of production.

The third management change (or need) deals with technology performance monitoring. Cost-benefit tracking can also be used to identify problems. Low productivity levels may be attributed to manufacturing operations even though the *real* cause may reside elsewhere. For example, an FMS may not produce the anticipated results if it is supported by a poor maintenance or material management system. Also, continual breakdowns or downtime associated with part shortages can limit the benefits projected for the FMS. Cost-benefit tracking should provide information regarding actual performance, so that management can determine whether enhancements to the technology itself are needed or whether problems exist in the surrounding support areas.

**Work steps for cost-benefit tracking**

In the previous article we dis-

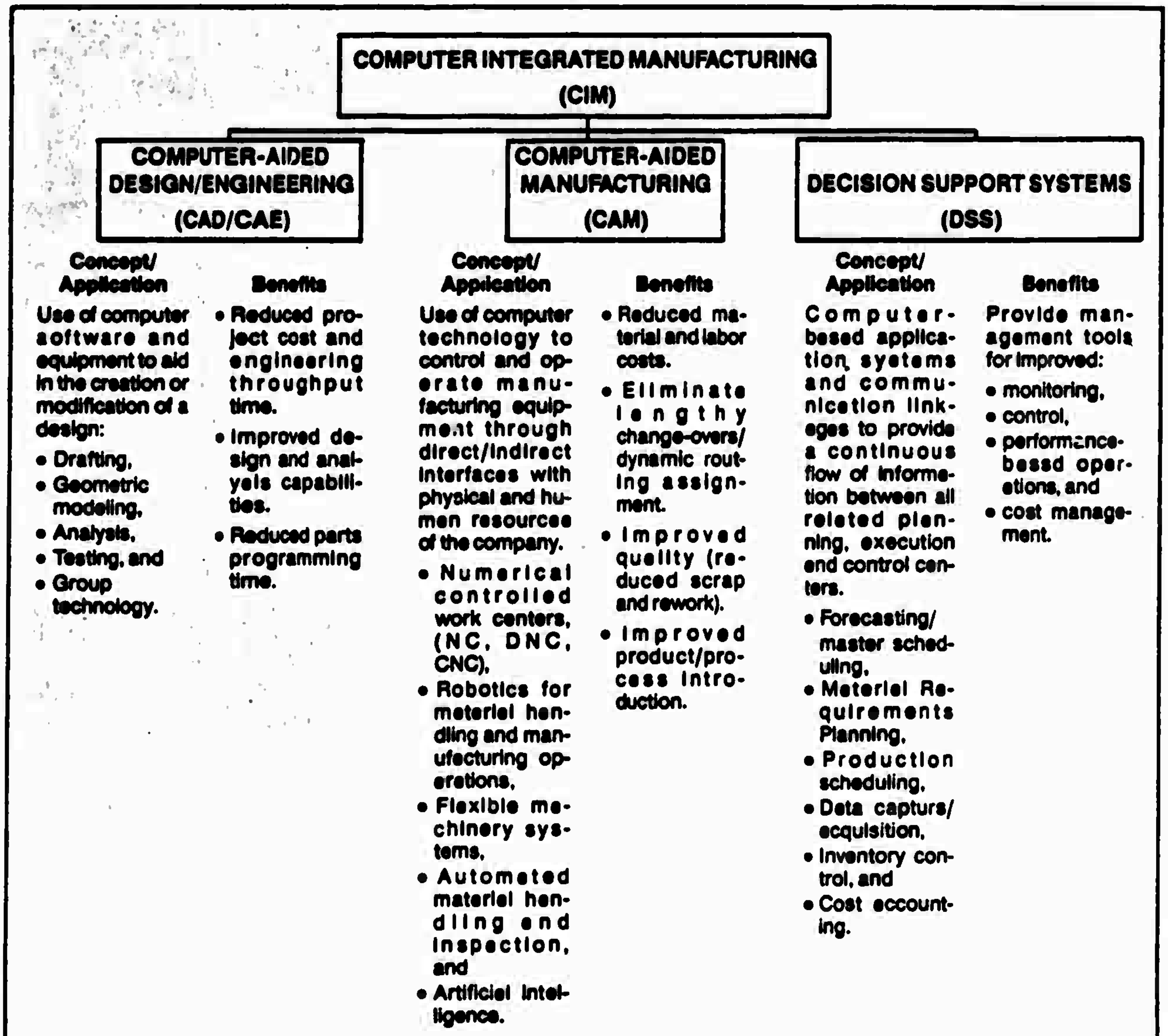



**Figure 2. The component functions of Computer Integrated Manufacturing**

cussed why technology management "winners" have come to learn the importance of cost-benefit analysis. In particular, two points should be reviewed before we outline the cost-benefit tracking work steps.

First, the key success factor approach is used to define what performance factors have an impact on the level of overall costs (cost baseline). Performance improvements should have a material and direct impact on the cost baseline.

Second, conceptual design activities should include the development of a "To Be" cost baseline, an assessment of benefits, risks and assumptions, and a general description of required cost-benefit tracking mechanisms.

These considerations are critical prerequisites to effective cost-benefit tracking. Stated more simply, planning must include what is to be measured and how the measurement will be accomplished. Upfront planning must include how the new technology will be *managed* as well as the implementation strategy. Figure 1 is an illustration of how cost-benefit analysis and cost-benefit tracking are integrated. The remainder of this article will describe a cost-benefits tracking approach which applies to most companies.

*Step 1: Capture actual cost information.* Cost-benefit tracking begins with the capture of actual data (costs) for the functional areas affected by the automation. The types of data to be captured typically include:

- Direct labor (standard, attendance factors, learning curve, scrap and rework);
- Direct material (standard, yield and scrap);
- Other direct costs (machinery and equipment, engineering, information systems, energy, inventory carrying costs, and other operations support);
- Indirect labor and material; and
- Other indirect costs (facilities, administrative information systems, G&A support, financing).

The actual cost elements to be tracked are determined by the cost model most appropriate for the given company. The data should be captured through a single integrated information system to support all cost management and performance reporting needs. Pertinent design issues which affect data capture include: the point of data capture, the method of data capture, controls over accuracy, and the timing difference between the occurrence of the transaction and its reporting.

The result of this work step is a data base of actual performance data and its associated costs, which will be used to: (1) analyze the key success factors for the functions affected by the automation, and (2) to support the company's overall data presentation needs. These data needs include: accounting information, pricing, general performance measurement and specific technology improvement monitoring.

Effective cost-benefit tracking incorporates the fundamentals of traditional financial analysis, cost management and statistical performance measurement and evaluation.

*Step 2: Determine the actual cost baseline.* Costs which are directly (completely and totally) attributable to the technology modernization project are analyzed on a project (functional) basis. Depending on the magnitude of the costs, this information is collected at the detail or summary level. All other costs are normally summarized and allocated as required. The result of this work step is the actual cost baseline.

*Step 3: Calculate the cost difference between the actual and the predicted ("To Be") cost baselines.* In this step it is important to make use of the key success factor/productivity "driver" analysis, assumptions developed during the conceptual design, and risk management aspects of the cost-benefit analysis. This information is used to analyze and reconcile significant variances between the actual and "To Be" cost baselines. This analysis is done for each major cost element determined to be a key success factor. Rate, production mix and quantity differences are examples of the types of variances which can be identified for each major cost element being tracked.

This work step results in variances being identified at operational level by cause. This information is then used to correct the problem, if possible. Otherwise, the projected "To Be" cost baseline (and process standard) should be revised. Revising the "To Be" cost baseline is normally restricted to conceptual design assumptions which do not hold true. Examples of assumptions which may require revising to "To Be" cost baseline include:

planned versus actual volume, learning curve factors, actual versus planned yield, and machine throughput performance considerations.

*Step 4: Close the technology planning loop by passing the actual cost baseline information back to the cost-benefit analysis model.* Actual cost baseline information should be used to determine any new improvement opportunities or to re-prioritize exisiting factory automation projects. Actual cost baseline information provides information to maintain a rank-ordered priority of technology modernization projects.

The result of this work step is a closed-loop technology management program. This information should be used to maintain an up-to-date effectiveness review/needs analysis.

*Step 5: Complete the required reporting.* The last step of the cost-benefit tracking model is to complete all required reporting. The implementation of a comprehensive cost-benefit tracking data base will support all internal and external reporting requirements. This information will provide the means to effectively monitor and control the technology-based environment.

The cost-benefit tracking model provides the infrastructure to support overall reporting requirements and "institutionalize" the necessary changes in management practices.

### Making it happen

Successful factory automation requires the formal integration of cost-benefit analysis and cost-benefit tracking. Technology improvement efforts must define what is to be measured and how the measurement will be accomplished. The purpose of cost-benefit tracking is, therefore, to monitor the critical cost factors and productivity "drivers" that have been identified by the cost-benefit analysis work effort. Effective cost-benefit tracking requires that the productivity "drivers" or key success factors be monitored as well as overall cost and performance.

The implication here is that the timing and content of data collection activities will change. Information regarding productivity "drivers" as well as actual cost data needs to be collected. Effective cost-benefit tracking incorporates the fundamentals of traditional financial analysis, cost management and statistical performance measurement and evaluation.

Effective cost-benefit tracking demands timely and accurate source data capture. The actual data to be collected should be at the lowest practical level of detail (work order/part/machine/operation).

Effective cost-benefit tracking

## How Technology Management applies to CIM

In its most basic form, the "Recapitalization of America" involves technology advances on three broad fronts:

(1) *Materials and product technologies* — carbon fibers, ceramics, large scale semiconductors, optical fibers, etc.;

(2) *Process technologies* — robotics, automated material handling, flexible machining systems, etc., and

(3) *Information technologies* — Manufacturing Resource Planning (MRP II), Computer-Assisted Design, group technology coding systems, telecommunications, etc.

The need for integration of these technologies and the attendant cost containment, quality improvement, schedule reduction and capacity control benefits is intuitively recognized by many. Integration efforts, admittedly incomplete, are currently taking place at two different levels of focus: first *within* each of several technology categories and then *between* the categories as a whole. These broad categories of technology are familiar to many as: Computer-Assisted Design/Engineering (CAD/CAE), Computer-Assisted Manufacturing (CAM), and Decision Support System (DSS). The integration effort between these categories is known generically as CIM, or Computer Integrated Manufacturing. (Figure 2.)

Today, CIM exists mainly as a "gleam in the eye" of some forward thinking managers. But many experiments are being tried (particularly a number supported by the Department of Defense Industrial Modernization Improvement Program). The day is not far off when a working CIM facility within a particular industry will be demonstrated.

Technology Mangement is the application of the managerial tools and techniques needed to first develop on a project basis — and then plan and control on a dynamic operating basis — a CIM facility. Technology Management is a mind-set change from a discrete work order/work cell basis of management to the *total* planning and controlling of a facility's cost, quality, scheduling and capacity profile.

**_Technology Management is a mind-set change from a discrete work order/work cell basis of management to planning and controlling the total of a facility's cost, quality, scheduling and capacity profile._**

avoids collecting unnecessary data, but it should be accompanied by a single integrated system to support the following types of cost and performance reporting needs:

- Ledger accounts,
- Organizational unit (cost center),
- Product,
- Job/work order (multiple orders within a job),
- Functional process,
- Project,
- Contract, and/or
- Fund.

It should be clearly understood that the design and implementation of the cost-benefit tracking system is a critically important technology management issue.

Many cost management systems in place today are not responsive to technology cost-benefit analysis and tracking needs. The cost system may have been originally developed years ago when manufacturing operations were less complex in terms of products, processes, logistics and labor force characteristics. It has been observed that the failure of many cost-benefit tracking efforts can be traced to an antiquated cost management system. An "antiquated" cost management system is characterized by:

- Direct labor as the only basis of production control and overhead allocation;
- A historical orientation, reporting what has happened, instead of planning what should happen;
- Inadequate information regarding support system cost factors such as material handling, inspection and maintenance (which are often lumped together into one factory overhead account);
- Lack of variable product/process cost information and the inability to identify, analyze and explain the cause(s) of significant variances at the operational level;
- Top management reporting which is limited to the same data given to line supervision; and
- Lack of integration between project, financial, manufacturing and cost management systems.

Successful technology cost-benefit tracking will require two fundamental but perhaps significant changes for some companies. First, recognition that the automated factory cannot be managed in the same manner as the "As Is" environment. This requires a careful examination of the implications of the design concepts and management control practices for the "To Be" manufacturing process or processes. Key success factors and productivity "drivers" will change as you move from the "As Is" to the "To Be" environment. Formal integration of the cost-benefit analysis and cost-benefit tracking work steps will enable companies to move to performance-based operations management.

Second, there may be a need to anticipate changes in the cost management system (data collection, reporting, cost classification and causal analysis) to support the automated factory environment. Many companies are finding that these two types of changes in management practices are providing benefits which equal or exceed the potential of factory automation technology.

**Conclusions**

The purpose of this three-part article has been to provide guidelines for improving the technology management process. Research studies have concluded that the introduction of new technology represents the single greatest opportunity for productivity improvement in this country. This consideration, coupled with increased international competition, indicates that technology management is a critical strategic issue. We have observed that technology management "winners" are those companies which:

- Include technology modernization planning within the strategic planning process;
- Allocate the necessary time, resources and skills to evaluate technology improvement opportunities;
- Recognize the relationship between technology and cost management (cost management needs to be an integrated and dynamic part of the technology management planning, control and measurement process);
- Anticipate changes in management practices and support systems in moving to a technology-based manufacturing position; and
- Recognize that effective cost-benefit analysis and tracking guidelines are a *critical prerequisite* for success.

Technology management is a strategic matter that companies must address to maintain their competitive position. The goal of every technology manager should be to develop a program which is affordable, realistic, reachable and consistent with the future strategic direction of the company. Future success will depend on mastering the technology management process.

# PRICE WATERHOUSE REVIEW CRITERIA

# CDEF

# COST-BENEFIT ANALYSIS AND TRACKING

The nine questions presented in this document highlight the major points that Price Waterhouse believes necessary to execute a successful cost-benefit analysis program. To summarize, an effective cost-benefit analysis process should address the following:

- It should evaluate the cost impact of an enhanced manufacturing technology on the manufacturing functions involved rather than the products being produced. Product cost reduction occurs as a result of process cost reduction - at given levels of volume and mix.

- It should prepare an analysis of, and plan to minimize, project risk (economic, technical and human factors).

- It should identify cost-benefit tracking requirements to aid in assuring realization of proposed benefits.

The nine questions which comprise the Price Waterhouse cost-benefit evaluation criteria are:

I. Has a functional structure been used?

The Node Tree diagram ($IDEF_0$ model) is an example of a functional structure which aids in establishing a "top-down" approach and in identifying each manufacturing function within a given project's scope. Consistency between functional manufacturing operations, financial reporting, performance improvement and cost-benefit analysis can best be achieved by structuring each on an equivalent basis. A functional structure of the project's scope provides the "common ground" for establishing this consistency.

By documenting all manufacturing functions within a project's scope, greater assurance is provided that total costs are recognized. This helps ensure that the overall planned reduction in cost is trackable and that cost shifting between functions does not go undetected.

II. Have Function Groups been identified?

Function Groups are defined as the group(s) of low-level functions (nodes) that are impacted by a given technology within the functional scope of the improvement project. Function Groups simplify the cost-benefit process by reducing the number of computations which need to be performed.

III. Has the financial reporting structure been "mapped" against the functional structure?

The mapping (overlay) of the financial reporting structure against the functional structure establishes input/output cost control. This mapping process links the cost-benefit analysis/ tracking process to the financial reporting process. This link is a critical step in assuring:

- The inclusion of incurred costs within the defined functional structure,
- The traceability of costs and benefits over time, and
- Reduction in the need for expensive statistical data collection systems for the purpose of calculating baseline data.

Also, because it is subject to mandated accounting controls and procedures, financial reporting is often a more stable data base than those developed from operational statistics.

IV. Has a comprehensive Manufacturing Cost Model been identified?

The purpose of a manufacturing technology improvement program is to reduce the "value-added" costs incurred within the defined functional scope of the project. To properly analyze, evaluate and monitor the change in value-added costs from the "As Is" to the "To Be" condition, they must be grouped on a common basis (i.e., a manufacturing cost model must be developed).

A typical manufacturing cost model groups costs by material segments (direct material is a pass through, not value-added; scrap is a negative value-added), labor segments (both direct and indirect) and overhead and support segments (utilities, equipment amortization, inventory carrying, facilities, payroll, personnel, engineering, etc.). Once the manufacturing cost model is prepared, costs can be input (at a given level of production volume and mix) into the functional scope of the project so that both the "As Is" and the "To Be" condition can be computed and compared. The project's savings are then the difference between the "As Is" and "To Be" input cost baselines, extended for the time horizon of the project.

## V. <u>Have Critical Success Factors and the related performance measures been identified?</u>

Critical Success Factors are defined as those criteria that <u>must be</u> satisifed if the expected goals of a given project are to <u>be attained</u>.

Performance measures are the criteria used to monitor the status of a Critical Success Factor. By using an approach to cost-benefit analysis/tracking that is function oriented and linked to the financial reporting system, performance measures can be quantified. Guidelines for establishing performance measures should include:

- o Measurability,
- o Direct linkage to the cost groups, and
- o Auditability (traceability) over time.

## VI. <u>Have "As Is" and "To Be" cost baselines been established?</u>

The primary reason for developing cost baselines is to provide a mechanism for monitoring and analyzing cost behavior pattern changes (quantify the benefits) as a given technology is implemented.

The advantages of the baseline approach, using functional data rather than product data, include:

- o An ability to do cross-functional impact analysis. As costs change within a function (or Function Group), they may adversely (or favorably) impact the cost patterns of another function (or Function Group). As enhanced manufacturing technologies are implemented, cost shifting will normally occur between functions and/or between cost groups within a function. For example, as the modules of IMS are implemented, production planning costs may decrease but data processing costs will probably increase. This cost shifting phenomenon is most visible using functional data and the baseline approach.

- o An ability to verify the source of the "As Is" data. Once the functional structure has been linked to the financial reporting system, the measurement of change from one baseline to another can be determined without processing large amounts of statistical data.

Thus, the "As Is" baseline can be verified to generally accepted financial data to assure that the <u>total cost</u> of the project's scope has been included.

## VII. Has project risk been considered?

By identifying and documenting the risk aspects of the project, alternative scenarios can be prepared. These scenarios are typically developed considering "Best Case/Worst Case/Expected Case" situations with various benefit relationships within the Function Group based on changing risk factors.

By establishing these scenarios, a risk management plan can be developed. This plan should outline the steps required to manage the risks that have been identified as having the greatest potential to inhibit benefits anticipated.

Project risks may exist in areas other than hardware technology. The "Human Factor" risk is always present in an environment where new technology is being implemented. For example, some of the human factor risks that might exist within a Flexible Machining System (FMS) environment are:

- o Adaptability of machining operators to the new environment, and
- o Ability to retrain those workers displaced by the new technology.

These are two of many human related risks that could impact a technology improvement project and which should be reflected in the cost-benefit process.

## VIII. Has the synergistic impact of the technology improvements been considered?

Whenever new manufacturing technologies are implemented, the impact of the technology seldom affects only one function (node). This effect, often referred to as "synergistic impact," must be considered in the cost-benefit process.

The functional approach to cost-benefit analysis, using a Function Group concept, provides the capability for the identification of these interrelated impacts on all the functions involved. This concept of synergistic identification becomes even more applicable when multiple projects with multiple technologies are being implemented simultaneously within a single program.

## IX. Has a benefits tracking plan been developed?

Cost-benefit tracking is a critical element of a comprehensive cost-benefit analysis process. Each segment of a successful and efficient cost-benefit tracking plan must correspond to the criteria set in the establishment of performance measures (see Question V).

A functional approach to cost-benefit analysis that is linked to the financial reporting system logically yields a tracking plan that utilizes interim financial reporting to measure changes in cost baseline behavior patterns. Variances between the "To Be" environment and the current environment can be readily quantified using this approach. This "financial-linked" approach to benefits tracking minimizes the need for additional and extensive statistical shop floor data collection systems.

It should be noted that while the functions/processes of a manufacturing organization are relatively stable, the product mix manufactured may fluctuate significantly over the life of a cost-benefit tracking program. If a product approach is used in performing the cost-benefit analysis, the tracking task, the explanation of variances and the adjustment of benefit expectations, could become a highly burdensome process.

# APPENDIX A.2

## Detailed Description of DCF/SSA Model

# APPENDIX

## DCF/SSA - Detailed Description

The Westinghouse Discounted Cash Flow/Shared Savings Analysis model has been created utilizing EXECUCOM Systems Corporation's Interactive Financial Planning System software package on Hewlett-Packard's HP3000 hardware.

The purpose of the DCF/SSA is to provide an evaluation tool for capital investment decisions by measuring a projected rate of return of proposed investment projects. An acceptable return rate is compared to the calculated net cash flow rate of return projection to ascertain financial feasibility.

## INPUT

Required inputs include projected investment and savings applicable to the project. Investment will include:

Project expense - annual expenditures for design, development, support, follow, etc.

Project capital - annual expenditures for the various categories of equipments as well as land, buildings, etc.

Savings will include three categories and must be identified in annual increments:

- Total Government savings
- Savings applicable to programs identified as participants in sharing.
- Commercial program savings

## OUTPUT

The salient output feature of the DCF/SSA model is the Net Cash Flow per annum. The output elements of the model's net cash flow line are:

1) CAS 409 Depreciation Recovery - straight line depreciation recovery (CAS409). Westinghouse utilizes the 1/2 year convention which yields 6.25% the first year, 12.5% the next seven years and 6.25% the ninth year.

2) Expense Recovery-
   - The IFPS model accounts for Recovery through labor rates of Expenses invested, discounted for a level of Commercial Business included in the business base.

     Assumption = 95% of expense investment is recoverable in the year of investment and 5% is recoverable during the following year.

3) Cost of Money (CAS 414)

   Utilizing the U.S. Department of the Treasury published rates, Westinghouse accounts for the facilities capital investment cost recovery discounted by the level of commercial business included in the business base.

4) Profit on Recoverables

The IFPS model allows for a percentage recovery of costs recovered at the direct cost level discounted for commercial business in the business base.

5) Loss on Savings

The IFPS Model accounts for the level of profit not realized due to the substantial level of savings generated. The average government savings per year times the negative value of the appropriate weighted guide lines profit level yields this value.

6) Retained Savings

The IFPS model provides for retention of savings allocated to any in process fixed price government contracts as well as any commercial business included in the business base.

## WESTINGHOUSE MODEL FORMAT

The model format contains fifty-one lines in its current configuration. The format is extremely flexible. Therefore, many desired features can be accommodated. There are three sections to the input file; the model, report and datafile.

The model format is as follows:

Line 10 sets up the number of columns. In the sample version there are eleven columns - ten years and one total.

Line 20 in the Expense input from the datafile. The model features a search function where it will search the datafile for a matched nomenclature keyed by the characters that precede the equals sign.

Line 30 is the building investment input.

Line 33 is the cumulative building investment.

Line 36 provides the building investment base to be utilized in the building depreciation calculations. (line 100).

Line 40 is the equipment investment in the five year depreciation category.

Line 43 is the cumulative calculator of line 40.

Line 46 provides the five year equipment base for depreciation calculations. (line 120).

Line 50 is the equipment investment in the eight year depreciation category.

Line 53 is the cumulative calculation of line 50.

Line 56 provides the eight year equipment base for depreciation calculations. (line 130)

Line 60 totals the equipment input.

Line 70 is the cash flow adjustment input.

Line 80 sums the capital category of investment.

Line 90 sums the total investment dollars.

Line 100 through 170 provide for the depreciation calculations of the capital investment.

Line 180 provides for the depreciation recovery calculation.

Line 190 provides for the expause recovery calculation.

Line 200 is the Government savings.

Line 210 is the Commercial savings.

Line 220 is the Major Program savings.

Line 230 provides for the incentive savings calculation as a percentage of the Major Program Savings.

Line 240 provides for the retained savings calculator.

Line 250 provides for profit on depreciation and expense recovery.

Line 260 averages the line 250 calculation.

Line 270 provides for the loss of profit savings.

Line 280 averages line 270.

Line 290 provides for the cost of money calculation.

Line 300 calculates the income before taxes (IBT).

Line 310 provides for this income after tax calculation.

Line 320 provides for investment tax credit or equipment investment.

Line 330 provides for the tax adjustment on the ACRS.

Line 340 provides for the tax adjustment on the expense recovery.

Line 350 sums the elements of Net Cash Flow.

Line 360 provides for the investment input of the Rate of Return calculation.

Line 370 provides for the cash flow input of the Rate of return calculation.

Line 380 provides for the function of next year rate of return calculations

Line 390 provides for the function of a ten year matrix rate of return calculation.

Line 400 sets of column eleven as a total column.

WESTINGHOUSE DCF/SSA MODEL

```
' MODEL TH  VERSION OF  12/20/85  08:30
10 COLUMNS 1-11
20 EXPENSE = 0
30 BUILDING = 0
33 CUM BLDG = L30 + PREVIOUS L33
36 PREV BLDG BASE = L33 - L30
40 EQUIPMENT 5 = 0
43 CUM EQUIP 5 = L40 + PREVIOUS L43
46 PREV EQUIP 5 BASE = L43 - L40 - PREVIOUS 5 L43
50 EQUIPMENT 8 = 0
53 CUM EQUIP 8 = L50 + PREVIOUS L53
56 PREV EQUIP 8 BASE = L53 - L50 - PREVIOUS 8 L53
60 EQUIPMENT = L40 + L50
70 CASH FLOW ADJ = 0
80 CAPITAL = L30 + L60 + L70
90 TOTAL INVESTMENT = L20 + L80
100 STLBLDGDEP = (L30/90) + (L36/45)
103 CUMSTLBLDGDEP = L100 + PREVIOUS L103
106 BLDG BK VALUE = L33 - L103
110 ACRS DEPR(15,1984,BUILDING,ACC BLDG DEP)
120 STL EQ5 DEP = ((L40 + PREVIOUS 5 L40)/10) + (L46/5)
123 CUM STL EQ5 DEP = L120 + PREVIOUS L123
126 EQ5 BK VALUE = L43 - L123
130 STL EQ8 DEP = ((L50 + PREVIOUS 8 L50)/16) + (L56/8)
133 CUM STL EQ8 DEP = L130 + PREVIOUS L133
136 EQ8 BK VALUE = L53 - L133
140 ACRS DEPR(5,1984,EQUIPMENT,ACC EQ DEP)
150 ST L DEPRECIATION = L100 + L120 + L130
160 ACC DEPRECIATION = ACC BLDG DEP + ACC EQ DEP
170 TOTAL BOOK VALUE = L106 + L126 + L136
180 DEPR RECOVERY = .94 * ((.95 * L150) + (.05 * PREVIOUS L150))
190 EXP RECOVERY = .94 * ((.95 * L20) + (.05 * PREVIOUS L20))
200 GOVT SAVINGS = 0
210 COMM SAVINGS = 0
220 MAJOR PROG SAVINGS = 0
230 INCENTIVE SAVINGS = .50*L220 FOR 5,.25 * L220,.00*L220
240 RETAINED SAVINGS = (.00 * L200) + L210
250 PROFIT ON DEPR = .12 * .94 * (L20 + L150)
260 DEPR PROFIT = .50 * (L250 + PREVIOUS L250)
270 LOSS ON SAVINGS = -.12 * L200
280 SAVINGS LOSS = .50 * (L270 + PREVIOUS L270)
290 COST OF MONEY = .10375 * .94 * (.50 * (L170 + PREVIOUS L170))
300 IBT = L230 + L240 + L260 + L280 + L290
310 IAT = .54 * L300
320 INVEST CREDIT = .08 * L60
330 ACC DEPR TAX ADJ = .46 * (L160 - L180)
340 EXPENSE TAX ADJ = .46 * (L20 - L190)
350 NET CASH FLOW = L180 + L190 + L310 + L320 + L330 + L340 - L90
360 ROR INVESTMENT = -L350, 0
370 ROR CASH FLOW = 0, L350 FOR 9
380 ROR = MDIRR(L370, L360)
390 IRR = MATRIX(L380, 10) * 100, 0
400 COLUMN 11 FOR L20 THRU L370 = SUM(C1 THRU C10)
END OF MODEL
```

DATAFILE FOR SAMPLE ROI ANALYSIS

```
?

 ?
DATAFILE TM
READY FOR EDIT. LAST LINE IS 0
?
 1 EXPENSE= 750,3750,2500.2500.500,0.0.0.0.0
2 BUILDING= 0 FOR 10
3 EQUIPMENTS= 0 FOR 10
4 EQUIPMENT 0= 0.2000,5000.4000.1000,0.0.0.0.0
5 CASH FLOW ADJ = 0 FOR 10
6 GOVT SAVINGS=0.250,5000.5250.5500,10000,10500.12000.12500.15000
7 COMM SAVINGS=0,0,50,75,300,600,650,650,700,750
8 MAJOR PROG SAVINGS=0.150.4500.5000,5000.7500.9000,9500.10000.10500
?
```

REPORT FOR SAMPLE ROI ANALYSIS

```
?

 REPORT TM  VERSION OF  08/01/85  10:54
 1 FORMAT..................    11[ 000000.0]
 2 COLUMNS 1-11
 3 SDATES
4 CENTER SAMPLE ROI ANALYSIS REPORT
 5 S
 6 COLUMN TITLES  YEAR 1, YEAR 2. YEAR 3. YEAR 4. YEAR 5. YEAR 6,'
 7                YEAR 7. YEAR 8. YEAR 9. YEAR 10, TOTAL
 8 UNDERLINE
 9 S
10 L20, SPACE. L60. L30, L70. L80. SPACE. L90, SPACE 2
11 L230, L180. L170. L260. L280. L290, L240. SPACE 2
12 L300, L310. L320, L330. L340. SPACE 2
13 L350, SPACE. L390
14 SPACE 2. L200. L210. L220
END OF REPORT
```

12/20/85

SAMPLE ROI ANALYSIS REPORT

| | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 | YEAR 6 | YEAR 7 | YEAR 8 | YEAR 9 | YEAR 10 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| XPENSE | 750.0 | 3750.0 | 2500.0 | 2500.0 | 500.0 | | | | | | 10000.0 |
| QUIPMENT | | 2000.0 | 5000.0 | 4000.0 | 1000.0 | | | | | | 12000.0 |
| UILDING | | | | | | | | | | | |
| ASH FLOW ADJ | | | | | | | | | | | |
| APITAL | | 2000.0 | 5000.0 | 4000.0 | 1000.0 | | | | | | 12000.0 |
| OTAL INVESTMENT | 750.0 | 5750.0 | 7500.0 | 6000.0 | 1500.0 | | | | | | 22000.0 |
| NCENTIVE SAVINGS | | 75.0 | [illegible] | 2500.0 | 2500.0 | 1875.0 | | | | | [illegible] |
| EPR RECOVERY | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1410.0 | 1410.0 | 1410.0 | 1270.4 | [illegible] |
| XP RECOVERY | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | | | | [illegible] |
| EPR PROFIT | 42.3 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| ETAINED SAVINGS | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| T | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| AT | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1300.3 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| NVEST CREDIT | | [illegible] | [illegible] | [illegible] | [illegible] | | | | | | [illegible] |
| CC DEPR TAX ADJ | | [illegible] | [illegible] | [illegible] | [illegible] | 516.6 | 317.4 | -166.6 | -552.0 | -597.3 | [illegible] |
| XPENSE TAX ADJ | 36.9 | 160.4 | 42.0 | 69.0 | -29.4 | -10.0 | | | | | 276.0 |
| ET CASH FLOW | -20.5 | -1616.7 | -2320.7 | -550.0 | 2791.7 | 3296.6 | 1047.9 | 1221.1 | 717.9 | 411.3 | 5761.0 |
| RR | 25.5 | | | | | | | | | | |
| VT SAVINGS | | 250.0 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| HR SAVINGS | | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| LUE PROD SAVINGS | | 150.0 | 4500.0 | 5000.0 | 5000.0 | 7500.0 | 9000.0 | 9500.0 | 10000.0 | 10500.0 | 61150.0 |

# LMI DISCOUNTED CASH FLOW MODEL

This section describes the Discounted Cash Flow (DCF) Model illustrated in Table B-1 and the spreadsheet program that calculates the various entries for it. The objective of the DCF Model is to provide a basis for analyzing a proposed Industrial Modernization Incentives Program (IMIP) business arrangement for the contractor, the Department of Defense (DoD), and the Government. The model has been prepared for use with a computerized spreadsheet financial program. Consequently, recalculation of the results with varying assumptions, particularly different incentive arrangements, is quite easy and should aid the negotiation process. The DCF Model is described by output report line number. Model input conventions are also described.

## CORE DATA (LINES 1-4)

The data appearing in this section are repeated automatically once specified in the model's input portion (see the bottom portion of Table B-1).

1. Contractor Investment. This is the time-phased forecast of expenditures for facilities to be acquired. Included are any costs normally capitalized by the contractor (e.g., installation costs). It is possible that the proposed facilities investment will be employed on both commercial and Government work, and on DoD programs other than those participating in the IMIP incentive. When multiple use of these facilities is anticipated, the investment value entered in the model should correspond to the share allocated to DoD work and not the entire investment value. The DoD-allocated share of investment should be based on the allocation method normally used to assign

## TABLE B-1. LMI DISCOUNTED CASH FLOW MODEL

| | | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|
| | Year: | 1 | 2 | 3 | 4 |
| **SECTION I. CORE DATA** | | | | | |
| 1 Contractor Investment | | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 Contractor Expenses | | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 DoD/Government Funding | | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 Savings Available to DoD | | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | | 0.0 | 0.0 | 0.0 | 0.0 |
| **SECTION II. INCREMENTAL CASH FLOWS** | | | | | |
| 5 Productivity Savings Reward | | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 Cost of Money (CAS 414) | xx% | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 CAS 409 Depreciation | | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 Profit Effect | | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 Subtotal: DoD Cash Flows to Contractor | | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 Salvage Value | | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 Contractor Before-Tax Cash Flow | | 0.0 | 0.0 | 0.0 | 0.0 |
| **SECTION III. TAX CALCULATIONS** | | | | | |
| 12 ACRS Depreciation | | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 Contractor Taxable Income | | 0.0 | 0.0 | 0.0 | 0.0 |
| 14 Contractor Income Tax | yy% | 0.0 | 0.0 | 0.0 | 0.0 |
| 15 Investment Tax Credit | zz% | 0.0 | 0.0 | 0.0 | 0.0 |
| 16 Contractor After-Tax Cash Flow | | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | | 0.0 | 0.0 | 0.0 | 0.0 |
| **SECTION IV. SUMMARY** | | | | | |
| 17 DoD Program Benefit (Without Incentive) | | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | $0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18 DoD Program Benefit (With Incentive) | | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | $0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19 DoD Payback Period | 0.0 years | | | | |
| 20 Government Benefit | | 0.0 | 0.0 | 0.0 | 0.0 |
| Cumulative Total | | 0.0 | 0.0 | 0.0 | 0.0 |
| 21 Government Payback Period | 0.0 years | | | | |
| 22 Contractor Internal Rate of Return | | | | | |
| Without Incentive | 0.0% | | | | |
| With Incentive | 0.0% | | | | |
| 23 Contractor Payback Period | 0.0 years | | | | |

| MODEL INPUTS: | Year | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|
| Contractor Investment .................. | | | | | |
| Contractor Expenses ..................... | | | | | |
| DoD/Government Funding ................ | | | | | |
| Savings Available to DoD .............. | | | | | |
| Productivity Savings Reward .......... | | | | | |
| Profit Effect ............................ | | | | | |
| Salvage Value ............................ | | | | | |
| CAS 414 Rate ................ | xx% | ...... | ...... | ...... | ...... |
| CAS 409 Depreciation: .............. | | ...... | ...... | ...... | ...... |
| Depreciation Method ...... | 1 | ...... | ...... | ...... | ...... |
| (1:Straight Line; 2:Sum-of-Years; 3:Sum-of-Years/Half-Year; 4:150% Declining Balance; 5:150% DB, Switch to St Line) | | | | | |
| Asset Service Life (years) | 8 | ...... | ...... | ...... | ...... |
| Year Placed into Service | 1 | ...... | ...... | ...... | ...... |
| ACRS Depreciation: .............. | | ...... | ...... | ...... | ...... |
| Depreciation Method ...... | 1 | ...... | ...... | ...... | ...... |
| (1:Standard ACRS Tables; 2:Straight Line) | | ...... | ...... | ...... | ...... |
| Asset Class (Service Life) | 5 | ...... | ...... | ...... | ...... |
| (3: 3-yr; 5: 5-yr; 10: 10-yr) | | ...... | ...... | ...... | ...... |
| Year Placed into Service | 1 | ...... | ...... | ...... | ...... |
| Contractor Tax Rate .......... | yy% | ...... | ...... | ...... | ...... |
| Investment Tax Credit Rate .. | zz% | ...... | ...... | ...... | ...... |
| Completed Contract - Tax Lag | 0 | years (0 implies no lag) | | | |

Cost Accounting Standard (CAS) 409 depreciation costs to DoD effort. Note that all DoD work, not just programs participating in the IMIP incentive, should be the basis for allocating the investment, since non-participating DoD programs also benefit from the investment and bear their share of investment-related costs such as depreciation and imputed cost of money.

Investment-associated costs that are reimbursed directly by the Government, such as IMIP Phase I and II expenses, are excluded here and reported on Line 3 (DoD/Government Funding). Investment-related costs reimbursed by the Government in overhead are also excluded from the DCF Model. They are included in the DoD Benefit Analysis (see Item 5.5 of Table 1 in the basic document), where they are recognized as part of overhead; they effectively "wash out" for the contractor and are considered only in the computation of Savings Available to DoD (Line 4).

Contractor investment expenditures are entered directly into the input portion of the spreadsheet, in the columns for the years when they are expected to be incurred. Year 1 is thus defined as the first year in which a contractor's capital expenditure occurs. Such expenditures may occur well before an asset is placed in service. The DCF Model allows for timing differences between expenditures and initial depreciation recovery (capitalization) by an input for the year the asset is first placed in service. Placing an asset in service in Year 3, for example, implies that expenditures began in Year 1 of the analysis, while capitalization begins in Year 3.

Additional investments for facilities placed in service after the initial investment is first capitalized can also be entered in the model's input portion. Investments entered in years after the initial investment is first capitalized are immediately capitalized in the year the investment is entered in the model.

2. Contractor Expenses. These items are for expenses associated with the above investment process that are incurred by the contractor and not reflected in Government contract pricing. IMIP Phase I and II expenses are examples, provided they are not reimbursed directly or indirectly by the Government. Other examples are engineering effort expended in conjunction with the investment that are not capitalized in the investment cost and not otherwise reimbursed by the Government. If such engineering effort is directly reimbursed by DoD, it is entered in the DoD/Government Funding line of the DCF Model's input portion. If reimbursed indirectly, it appears in Item 5.5 of the DoD Benefit Analysis. Contractor expenses are entered in the DCF Model for the year incurred. Generally, they are prior to or coincident with the year in which the asset is placed in service and depreciation recovery begins.

3. DoD/Government Funding. DoD/Government Funding is the total DoD and other Government cost of implementing the IMIP -- funded directly. This cost generally results from DoD-initiated projects funded directly by DoD. Investment-related costs reimbursed indirectly in overhead are included in Item 5.5 of the DoD Benefit Analysis as noncapitalized investment expenses.

Line 3 costs are entered directly into the program in the column for the year they were or are expected to be incurred. In all likelihood, these costs represent early Phase I and II effort and thus occur before any contractor expenditures for facilities acquisitions. Since Year 1 is defined as the initial year when facilities-related costs occur, Line 3 costs already may have occurred before Year 1. Direct DoD/Government funding affects only DoD/Government benefits and costs and not contractor cash flow or return. Consequently, Line 3 costs incurred before Year 1 can be summed and entered in Year 1 of the analysis.

4. Savings Available to DoD. These savings come from Column 6 of the DoD Benefit Analysis, which should be prepared on an annual basis over the life of the program or service life of the assets (see Appendix A). The annual dollar value is entered directly into the input portion of the program for the year in which the Savings Available to DoD are anticipated to occur. If supportable, Savings Available to DoD can be entered for years beyond the life of a particular program, and even beyond the useful service life used for asset depreciation purposes. The period of analysis for the DCF Model is user-specified and generally should conform to the service life used for asset depreciation purposes.

The next two sections together comprise the contractor incremental cash flow analysis: Lines 5-11 give the before-tax cash flow, and Lines 12-16 are used to calculate the after-tax cash flow. The after-tax cash flow stream is then used to determine the contractor's internal rate of return (IRR) on his facilities investment.

INCREMENTAL CASH FLOWS (LINES 5-11)

5. Productivity Savings Reward. This is the amount of incentive payment to the contractor to encourage the proposed facilities investments under the IMIP concept. The incentive is funded, in principle, from a portion of the Savings Available to DoD. Cost savings on existing, priced contracts may accrue partly or totally to the contractor, depending on the type of the contract. If existing contracts priced before the proposed investment will benefit from the investment, the benefits to the contractor may be included as if they were part of the incentive payment.

It is anticipated that the contractor will propose the Productivity Savings Reward. The DCF analysis will show the contractor's IRR implied by the proposed incentive. The incentive can then be adjusted upward or downward until agreement is reached. No unique incentive stream is associated with a particular contractor IRR. Instead, a selected stream can be tailored to particular contracting circumstances while achieving the desired contractor IRR.

The Productivity Savings Reward is entered directly by the user. The program will evaluate this proposal. Line 22 displays the contractor IRR for the Productvity Savings Reward and also that which results when no incentive is provided.

6. Cost of Money (CAS 414). CAS 414 "Imputed Facilities Capital Cost of Money" is included in contract price as an allowable cost (see Federal Acquisition Regulation (FAR) 31.205-10). The payment is an element of contractor cash inflow, since it is an imputed cost; for the contractor there is no corresponding cash outflow. The CAS 414 payment is based on the remaining undepreciated balance (i.e., net book value) of the proposed facilities investment. For each year, the beginning and ending net book values are averaged to determine the applicable book value. This average book value is then multiplied by the "cost of money rate," supplied by the user as an input, to yield the total dollar payment for CAS 414. The entire calculation is automatically performed by the model.

7. CAS 409 Depreciation. Annual depreciation expense is an allowable cost on Government contracts under FAR 31.205-11 and is a source of cash inflow to the contractor. Depreciation is the delayed cash inflow that offsets the initial cash outflow incurred to acquire additional facilities. The annual amounts appearing on this line depend on the asset service life and the method of depreciation used. The amounts appearing are generated automatically by the program after selection of service life, the year capitalization

begins, and depreciation method for the asset value assumed. In the event CAS 417 applies, the capitalized acquisition value may be increased to conform with it.

The model allows for selection from among a number of the more common methods of depreciation encountered in practice. This selection is accomplished by entering the number of the selected method and the asset service life in years in the program's input portion. The methods available and a description of the techniques used to generate annual CAS 409 depreciation are as follows:

Method 1. Straight Line: This method assumes an equal amount of depreciation in each year of the asset service life. The annual depreciation amount is given by the formula:

$$\text{Annual Depreciation} = \frac{\text{Cost - Salvage Value}}{\text{Asset Service Life}}$$

Cost is defined as the full asset acquisition cost, including all costs normally capitalized. It is reduced by the estimated salvage value for depreciation purposes, but only if the salvage value is 10 percent or more of the total asset acquisition cost.

Method 2. Sum-of-Years Digits: Annual depreciation is given by the formula:

$$\text{Annual Depreciation} = \frac{\text{Number of Remaining Years Service Life x (Cost - Salvage Value)}}{\text{Sum-of-the-Years Digits Service Life}}$$

The Sum-of-the-Years Digits Service Life is computed by adding the digits of the number of years in the asset service life. For example, if the asset service life is five years, the digits 1 through 5 total 15 (1+2+3+4+5), and the first year's depreciation is 1/3 (5/15) of the total to be amortized. The depreciation basis is full asset acquisition cost less salvage value. As with Method 1, if salvage value is less than 10 percent of acquisition cost, salvage value is treated as zero for purposes of depreciation calculation.

Method 3. Sum-of-Years Digits with Half-Year Convention: This method applies a Half-Year Convention to the Sum-of-Years Digits Method. Under it, the annual depreciation amounts are computed exactly as in the Sum-of-Years Digits described in Method 2; however, the amounts to be depreciated are shifted by one-half year. Thus, in the first year, one-half of the amount computed in Method 2 is allowed. In Year 2, the remaining depreciation from Year 1 and one-half the Method 2 depreciation amount for Year 2 are allowed. This one-half year shift continues until the end of the asset service life. One year after the asset service life ends, the remaining one-half of the Method 2 depreciation amount is taken.

Method 4. 150 Percent Declining Balance: The annual depreciation expense for this method is computed as follows:

Annual Depreciation =
(1/Asset Service Life) x 1.5 x (Cost - Accumulated Depreciation)

Under this method, the cost is not reduced by the salvage value in the depreciation calculations; however, the asset is depreciated only down to its salvage value. As with the other methods, salvage value is ignored if it is less than 10 percent of the acquisition cost.

Method 5. 150 Percent Declining Balance with Switch-over to Straight Line: This method uses the declining balance described in Method 4. However, a switch-over to straight-line depreciation (Method 1) is made at the point where the declining balance depreciation amount becomes less than that which would be allowed under the straight-line method. Again, depreciation is not allowed below the salvage value, and salvage value is ignored for values less than 10 percent of the acquisition cost.

NOTE: These methods include the most likely patterns of allowable depreciation for contract cost purposes. Sometimes, however, a contractor's proposal may employ a different stream of depreciation charges (one reason might be a project that includes assets with different service lives). Under these circumstances, the user may ignore this part of the input portion (see the bottom portion of Table B-1) and supply directly to Line 7 of the output portion the year-by-year depreciation amounts.

8. Profit Effect. The contractor's total profit effect reflects the fact that IMIP investments result in profit dollars that vary from what would have been negotiated with the old method of production. IMIP investments usually result in a net reduction in "contractor effort," so that profit will ordinarily fall. This effect may be offset by a change in the mix of costs incurred from costs that bear low profit (e.g., material acquisition) to costs bearing higher rates of profit (e.g., engineering labor). In addition, the investment in facilities capital increases the contractor's facilities capital base, which bears profit under Weighted Guidelines. Column 5 of the DoD Benefit Analysis provides a format for measuring the net effect of the investment on annual contractor profit. The annual values are entered into the spreadsheet input portion in the columns for the years in question. The profit effect, if not negative initially, will usually become negative over time as annual depreciation and undepreciated balances both decline and the full cost-saving effects of the investment are realized.

9. Subtotal: DoD Cash Flows to Contractor. This subtotal represents the before-tax cash flow to the contractor from DoD arising from the contractor's facilities investment. Cash flow from DoD to the contractor is

the sum of the Productivity Savings Reward payment (Line 5), CAS 414 imputed facilities capital cost of money (Line 6), CAS 409 depreciation on additional facilities capital (Line 7), and the profit effect (positive or negative) given by Line 8. The DoD cash flows to the contractor represent the additional cash flow stream to the contractor arising from the investment and its effects on contract price. Cash flow from DoD to the contractor is calculated automatically by the program.

10. Salvage Value. Salvage value represents an anticipated cash inflow to the contractor at the end of the investment's estimated service life. Salvage value, if significant, may be entered in the DCF Model's input portion for the last year of the asset's depreciable service life. For applicable depreciation methods, salvage value is automatically deducted from the CAS 409 depreciable basis when it is 10 percent or more of acquisition costs.

11. Contractor Before-Tax Cash Flow. Before-tax cash flow to the contractor is the difference between all cash outflows and all cash inflows to the contractor. Cash outflows are contractor investment (Line 1) and contractor expenses (Line 2). Cash inflows are given by DoD cash flows to the contractor (Line 9) and salvage value (Line 10). Annual contractor before-tax cash flow is then the sum of Lines 1, 2, 9, and 10, where outflows are treated as negative values and inflows are positive.

Contractor before-tax cash flow is automatically calculated by the DCF Model. The sign of the annual value denotes whether the contractor enjoys a net inflow (positive) or outflow (negative). Generally, contractor before-tax cash flow is negative (an outflow) in the early years of the analysis, as a result of the facilities acquisitions. The cash flow stream usually turns positive (a net inflow) following the facilities acquisition and remains positive for a number of years. A net outflow may reoccur when the undepreciated book value of the assets declines to a low value and depreciation, CAS 414 payments, and Weighted Guidelines profit on facilities capital employed are concomitantly low.

TAX CALCULATIONS (LINES 12-16)

The objective of the next five lines is to calculate the contractor's Federal income tax consequences arising from the investment. Once tax liability is determined, contractor after-tax cash flow can be determined as the difference between before-tax cash flow and the incremental tax consequences of the investment.

12. Accelerated Cost Recovery System (ACRS) Depreciation. Additional contractor net cash revenues (i.e., contract sales dollars) are subject to Federal income taxes. Under tax law, the contractor is allowed to deduct depreciation charges from additional net cash revenues, using ACRS depreciation guidelines. Additional contractor net cash revenues, less ACRS depreciation charges, determine incremental income subject to Federal income taxes. ACRS tax depreciation generally differs from CAS 409 cost principles depreciation. Under tax conventions, the depreciable basis to which ACRS depreciation is applied is reduced to 95 percent of the capitalized value of the investment. This treatment reflects the convention applicable under tax code when a 10-percent investment tax credit is taken. If a reduced investment tax credit is taken, the depreciable basis for ACRS depreciation is 100 percent of the asset's capitalized acquisition value.

The annual ACRS tax depreciation charges appearing on Line 12 are generated by the program on the basis of the value of the contractor's investment (Line 1) and the ACRS tax depreciation method selected. The user selects the ACRS method from the two available methods (standard tables or straight line) displayed in the input section. The user must also specify the asset service life (called cost recovery class) applicable to ACRS tax depreciation. The user also specifies the year that the asset is placed in service for ACRS depreciation purposes.

ACRS Depreciation Methods

Method 1. Standard ACRS Tables for Three-, Five-, and Ten-Year Cost-Recovery Classes: This method uses rates provided by standard Internal Revenue Service tables for the various cost-recovery classes. The rates in these tables are applied to the full acquisition cost. If a full investment credit is taken for the particular class (10 percent for five- and ten-year and 6 percent for three-year), the depreciation base is reduced by one-half the investment credit taken. Salvage value is ignored under this method.

Method 2. Straight-Line: In lieu of the standard ACRS depreciation allowances, the user may instead select the straight-line method. The annual depreciation allowances are computed according to the specified asset service life without regard to salvage value.

13. Contractor Taxable Income. Income subject to Federal income tax is the difference between the contractor's additional net cash revenues and ACRS tax depreciation charges. Additional net cash revenues associated with the facilities investment are DoD Cash Flows to Contractor (Line 9) plus Salvage Value (Line 10) minus Contractor Expenses (Line 2). Taxable income in Line 13 is thus additional net cash revenues (Line 9 plus Line 10 minus Line 2) minus ACRS depreciation charges (Line 12). Taxable income is computed automatically by the DCF Model for each year covered by the analysis.

14. Contractor Income Tax. Income subject to Federal income tax, given by Line 13, times the contractor's applicable Federal income tax rate, determines the dollar value of the Federal income tax liability. The tax rate used should be that applicable to additional taxable income; i.e., the

contractor's marginal Federal income tax bracket. Generally, this will be 46 percent, although other rates can be used if appropriate. This procedure assumes that the Federal income tax liability is paid in the year in which it accrues. If the contractor defers the liability under the "Completed Contract Method," the cash outflow for Federal income taxes is postponed until contract completion. To allow for this possibility, a user-specified lag has been introduced into the DCF Model. The user specifies the number of years by which the cash outflow for income taxes lags behind the accrued tax liability. A two-year lag, for example, means that the tax liability in Year 1 is paid in Year 3, the liability in Year 2 is paid in Year 4, and so on. All unpaid taxes are assumed paid in the final year of the analysis. Finally, note that income tax refers only to Federal income taxes; state, local, and other taxes are allowable costs and are generally reimbursed as indirect costs (see FAR 31.205-41).

15. Investment Tax Credit. An investment tax credit is added to contractor cash inflow or, equivalently, subtracted from the contractor's tax liability, to reflect the investment tax credit applicable under tax law. The credit is generally calculated using 10 percent of the asset's capitalized acquisition value and credited when the asset is first placed in service. A 6-percent credit applicable to assets in a three-year cost recovery class is also possible. The DCF Model automatically applies a 10-percent investment tax credit for the year the asset is placed in service and capitalized. The 10-percent credit is applied to the cumulative value of Line 1 investment up to the time the asset is placed in service. The user can override the 10-percent credit with another value (e.g., the 6 percent applicable to the three-year cost recovery class). User input for the investment tax credit percentage is described in the input portion.

16. Contractor After-Tax Cash Flow. This stream represents the incremental net cash flow accruing to the contractor as a result of the investment. This stream is the one representing the financial outcome of the contractor's investment and the one from which an IRR is computed. After-tax cash flow is computed by subtracting contractor income taxes, adjusted for any investment tax credit, from before-tax cash flow. Thus, the contractor's after-tax cash flow (Line 16) is the sum of Lines 11, 14, and 15, where a positive value reflects a cash inflow and a negative value a cash outflow.

SUMMARY (LINES 17-23)

The summary begins with DoD and Government benefits; a year-by-year tracking of costs and benefits arising from the contractor investment. Benefits to DoD are those listed in Line 4, Savings Available to DoD. These benefits were calculated from Column 6 of the DoD Benefit Analysis as the potential contract price change arising from the productivity-enhancing investment before any Productivity Savings Reward payments. Thus, the DoD Program Benefit is equal to Line 4, Savings Available to DoD, less any Productivity Savings Reward (Line 5) and DoD/Government Funding (Line 3). Under this definition, a positive value indicates a net benefit to DoD (i.e., price reduction in excess of incentives and direct funding), while a negative value indicates a cost to DoD. The Government benefit reflects tax recoupment by the Government and thus generally exceeds DoD Program Benefit.

17-18. DoD Program Benefit. DoD Program Benefit represents the annual net benefit, if positive, or cost, if negative, from the IMIP investment. This value is the difference between the annual price reductions anticipated from the investment (Savings Available to DoD, Line 4) less any Productivity Savings Reward payment (Line 5) and DoD/Government Funding (Line 3). Typically, DoD Program Benefit is negative (i.e., a cost) in early years of the analysis, when funding and cash flow payments by DoD to the contractor are at their high levels. Line 17 gives DoD Program Benefit when the Productivity Savings Reward of Line 5 is set at zero. The purpose of this calculation is to indicate the magnitude of DoD Program Benefit without an incentive payment. Line 18 shows DoD Program Benefit after deduction of the Productivity Savings Reward.

19. DoD Payback Period. DoD and Government returns are indicated by payback periods: the number of years from the time benefits are first negative until they become positive. Payback is a particular representation of return where discounting is not performed and the value of benefits and costs beyond the payback period is not considered. Payback period represents the time required to match DoD-incurred costs with benefits. DoD benefits are likely to be negative (i.e., costs) during the early period of the analysis, since savings benefits are usually phased in slowly and related costs such as depreciation and CAS 414 payments are at their highest level during that period. The model automatically computes the DoD payback period using DoD Program Benefit (Line 18). Payback period is computed as the amount of time the cumulative value of Line 18 is negative.

20. Government Benefit. This value is found by adding the contractor's tax payment, less any investment tax credit, to the net DoD Program Benefit. Generally, Government Benefit exceeds DoD Program Benefit and thus the Government payback period is shorter than the DoD payback period. The model automatically computes Line 20, Government Benefit, by adding Contractor Income Tax (Line 14) to DoD Program Benefit (Line 18) and deducting Investment Tax Credit (Line 15). Thus, the Productivity Savings Reward payment is always included in the calculation of Government Benefit.

21. Government Payback Period. This measure of return to the Government is calculated on the basis of the Line 20 benefit/cost stream. It represents the time required for the Government to recoup, in the form of benefits, all Government cost incurred for the project. The model automatically computes the Government payback period by considering the amount of time the cumulative totals of Line 20 are negative.

22. Contractor IRR. The contractor IRR is based on the after-tax cash flow stream reported in Line 16. The IRR associated with this cash flow represents that rate which equates the present value of cash inflow to the present value of cash outflow. Since Line 16 is net cash flow, a negative entry in any one year represents a net cash outflow and, conversely, when the entry is positive, a net cash inflow.

Two IRRs are computed in the model: one rate considering the after-tax cash flow exclusive of any Productivity Savings Reward and the other including the proposed Productivity Savings Reward. The former IRR sets a floor from which the IRR can be increased by payment of such an incentive. The IRR is computed by a built-in routine in the spreadsheet program.

23. Contractor Payback Period. In addition to IRR as a measure of the financial outcome of the contractor investment, a payback period computation is included in the model. Payback period tells the contractor the number of years required to recoup his investment-related cash outflow. As with any payback computation, the time value of money (i.e., discounting) and the value of benefits beyond the payback period are not considered. Contractor payback includes the Productivity Savings Reward payment and represents the number of years from the point where the cumulative after-tax cash flow is first negative to the time when it becomes positive.

MODEL INPUTS AND CONVENTIONS

A complete run of the DCF Model is accomplished by specifying a number of inputs. These inputs may take the form of annual values, single rates, or integer values denoting accounting methods or conventions used in the model. Inputs and conventions of the model are described below:

1. Number of Years of Analysis. The user selects the number of years of display desired at the outset of the analysis, by pressing the "ALT" and "A" keys simultaneously. The user is then asked to specify the number of years desired (a value between 2 and 15). The program automatically adds the desired number of columns.

2. Inputs of Annual Values. Annual values are required for seven variables in the first part of this Appendix. The annual values for these variables are entered in the model input section and then are automatically reproduced in the appropriate lines of the DCF Model output report. The following sign conventions apply to these values:

- Contractor Investment - positive or zero.
- Contractor Expenses - positive or zero.
- DoD/Government Funding - positive or zero.
- Savings Available to DoD - A price reduction is denoted by a negative sign in Column 6 of the DoD Benefit Analysis (see Table A-1 in Appendix A). Such a reduction is entered with the opposite sign in the DCF Model. (Positive values in the DCF Model for this line represent savings to DoD, while negative values indicate costs to DoD).
- Productivity Savings Reward - positive or zero.
- Profit Effect - Enter with the same sign as found in Column 5 of the DoD Benefit Analysis. A negative sign indicates "lost profit" to the contractor and, conversely, positive values indicate increased contractor profit.
- Salvage Value - positive or zero.

3. Rates and Accounting Conventions.

- CAS 414 Rate - decimal equivalent; e.g., 11.5 percent entered as 0.115.

- CAS 409 Depreciation Method - an integer between 1 and 5, corresponding to the method selected.

- Asset Service Life - an integer equal to the number of years of asset service life assumed.

- Year Placed into Service - an integer value corresponding to the year the asset is first placed in service and CAS 409 depreciation begins.

- ACRS Depreciation Method - an integer corresponding to the method selected (1 or 2).

- Asset Class for ACRS - an integer corresponding to possible ACRS service life; 3, 5, or 10 for ACRS Method 1 but an integer specifying the asset service life for ACRS Method 2.

- Contractor Tax Rate - marginal Federal income tax rate entered as the decimal equivalent, such as 0.46.

- Investment Tax Credit Rate - a percentage rate, generally 10 percent, entered as the decimal equivalent; e.g., 0.1.

- Completed Contract-Tax Lag - an integer value representing the lag in years between the year in which the tax liability accrues and when it is paid (0 implies no lag).

# APPENDIX A.3

## Detailed Description of MFPMM

## MFPMM Basics

As we have mentioned earlier, productivity measurement can be impeded by product variety and the multiplicity of various resources utilized. Person-hours cannot be combined with tons of steel, dollars of capital equipment, kilowatt-hours, and so forth for a resource total. Nor could a Westinghouse or a General Electric add up the number of motors, refrigerators, electrical components, and so forth to get a measure of total product. The dollar, in the case of the United States, is a convenient common denominator.

Since productivity gains or losses are distributed via the price system (the customer, stockholder, owner, and employee benefit or lose according to shifts in productivity), it seems appropriate to use the yardstick of that system—money—to analyze the distribution. However, the dollar or any other currency is, particularly in the current economic period, a variable standard. Therefore, in order to use the dollar as an aggregating measure, the variability needs to be taken out (Davis, 1955). One major characteristic of the model to be presented is a requirement for and incorporation of a "revaluing," devaluing, or indexing mechanism. In essence, the model "partials out" or holds constant price and cost changes over time. This is accomplished either with the actual revaluing of outputs and/or inputs prior to use in the model or by selecting a base period for the model and "automatically" indexing prices and costs back to that period.

The basic concept of productivity measurement utilizing constant value prices and costs is presented in Table 5.2. As one can see, by revaluing or indexing to base year values, the analysis simply partials out or removes the influence in price and cost changes from the base year or period to the current year or period. What remains is the constant dollar value of output and input resources consumed. When these two values are compared for the base year, we establish a productivity ratio labeled output per dollar of input. When the current year or period productivity ratio is compared to the base year or period, we establish a productivity index. This table and these measures of productivity are consistent with the development presented in Chapter 2.

From a pragmatic business sense, the underlying purpose of productivity measurement and evaluation is to improve business operations and competitive position so as to enhance accomplishment of longer-term goals of survival, profitability, missions, effectiveness, and so forth. "Without productivity objectives, a business does not have direction. Without productivity measurement, it does not have control" (Drucker, 1980). The MFPMM can be utilized to measure productivity change in labor, materials, energy, and even capital, although it is not explicitly treated in this book. It can also be used to measure the effects of these changes separately as well as in aggregate on corresponding change in business profitability or, in the case of public-sector nonprofit firms, in budget maintenance. As van Loggerenberg and Cucchiaro (1982) point out, this "new" technique can be utilized to

1. Monitor historical productivity performance and measure how much, in dollars, profits were affected by productivity growth or decline
2. Evaluate company profit plans to assess and determine the acceptbility and reasonableness or productivity changes in relation to those plans

**Table 5.2 Illustrative Calculation of Productivity Change Using Output and Input Data Revalued at Constant Prices**
(Output and input totals in millions of dollars)

| ITEM | BASE YEAR | GIVEN YEAR REVALUED AT BASE-YEAR PRICES |
|---|---|---|
| *Case A. Increase in Productivity: Profits Earned Both Years* | | |
| Value of output | $200 | $275 |
| Cost of input (including profit at base-year rate) | $200 | $250 |
| Output per dollar of input | $ 1.00 | $ 1.10 |
| Productivity change, given/base year: | | |
| Percentage | | + 10 percent |
| Per dollar of input | | +$ 0.10 percent |
| Total dollars | | +$ 25 |
| *Case B. Increase in Productivity: Losses Incurred Both Years* | | |
| Value of output | $170 | $252 |
| Cost of input | $200 | $280 |
| Output per dollar of input | $ 0.85 | $ 0.90 |
| Productivity change, given/base year: | | |
| Percentage | | + 5.9 percent |
| Per dollar of input | | +$ 0.05 |
| Total dollars | | +$ 14 |
| *Case C. Decrease in Productivity: Profits Earned Both Years* | | |
| Value of output | $200 | $228 |
| Cost of input (including profit at base-year rate) | $200 | $240 |
| Output per dollar of input | $ 1.00 | $ 0.95 |
| Productivity change, given/base year: | | |
| Percentage | | − 5 percent |
| Per dollar of input | | −$ 0.05 |
| Total dollars | | −$ 12 |

SOURCE: H.S. Davis, *Productivity Accounting*, 1955. Reprinted with permission.

3. Measure the extent to which the firm's productivity performance is strengthening or weakening its overall competitive position relative to its peer group(s)

These three uses for the MFPMM in addition to the eight additional uses mentioned earlier represent significant benefits accruable from this model.

An organization's financial performance (one of the seven measures of performance previously mentioned) is a result of interactions of a wide variety of controllable and uncontrollable factors. Managers in organizational systems attempt to improve performance by managing (allocating, utilizing, controlling, delegating, and so forth) resources under their control while being constrained or influenced by the uncontrollable factors. Typical uncontrollable factors are

- economic environment
- industry/market growth or decline
- resource prices (costs), particularly in an inflationary period
- rates of inflation for product prices versus resource costs
- budget allocation
- organizational processes and procedures

Typical controllable factors are

- technological innovation
- resource substitutions
- training and motivaton of employees
- asset redeployment
- resource quality

It is interesting to note that a number of variables will influence or determine which specific factors a given manager preceives as controllable or uncontrollable. Such variables as position with the firm, personality type, leadership style, and locus of control will shape the manager's perceptions. It would seem reasonable that a manager's actual behaviors are affected more directly and strongly by perceptions than "reality." Managers today view themselves as being significantly constrained by uncontrollable factors. This is a potentially consequential dilemma with respect to prospects for productivity improvement.

The MFPMM makes it possible to measure explicitly, in terms of dollars the profit impacts of these uncontrollable as well as controllable factors and to determine and analyze how various management strategies could increase or decrease profitability. Fundamentally, profit change comes about because of a difference between revenues and costs. If revenues increase faster than costs, there would obviously be a positive change in profits (see Figure 5.1). Yet revenues and costs do not always present a complete picture because of underlying complex relationships between controllable and uncontrollable factors. Therefore, as Davis, and Scott (1950) before him, pointed out, "[t]he net profit figure alone is an inadequate basis for judgment as to whether industrial operations are being carried out efficiently and labour and materials utilized effectively; it may merely tell us that a satisfactory balance has been struck between the value received and the value given." With essentially the same basic accounting information used to calculate revenues and costs, however, it is possible to use the MFPMM to gain additional and significantly more detailed insight into what is driving profits.

Column 1 of Figure 5.2 depicts, as presented in Chapter 2, the basic productivity index relationship, a change in output quantities over a change in resource quantities. In every organizational system, there exists a unique productivity index for each resource. Column 2 depicts what has been called a "price recovery

$$\frac{\text{Total Revenue (TR)}}{\text{Total Cost (TC)}} = \frac{\sum_{i=1}^{n} Q_i^O p_i^O}{\sum_{i=1}^{m} Q_i^I p_i^I} = \text{a measure of profitability}$$

where: $Q_i^O$ = quantities of type $i$ output (superscript $O$)
$p_i^O$ = the unit price for each output type
$Q_i^I$ = Quantities of type $i$ input type (superscript $I$)
$p_i^I$ = the unit cost for each input type
$n$ = the number of different types of output
$m$ = the number of different types of input

$$\frac{\Delta TR}{\Delta TC} = \frac{\dfrac{\left(\sum_{i=1}^{n} Q_i^O p_i^O\right) \text{period}_2}{\left(\sum_{i=1}^{n} Q_i^O p_i^O\right) \text{period}_1}}{\dfrac{\left(\sum_{i=1}^{n} Q_i^I p_i^I\right) \text{period}_2}{\left(\sum_{i=1}^{n} Q_i^I p_i^I\right) \text{period}_1}} = \text{measure of change in profitability}$$

**Figure 5.1 Profitability Assessment**

$$\begin{array}{ccccc}
\Delta \text{ in output quantity} & \times & \Delta \text{ output price} & = & \Delta \text{ revenue} \\
\parallel & & \parallel & & \parallel \\
\dfrac{\sum_{i=1}^{n} [(Q_i^O) \text{ period}_2}{\sum_{i=1}^{n} [(Q_i^O) \text{ period}_1} & \times & \dfrac{(p_i^O) \text{ period}_2]}{(p_i^O) \text{ period}_1]} & = & \dfrac{\text{TR period}_2}{\text{TR period}_1} \\
\hline
\dfrac{\sum_{i=1}^{m} [(Q_i^I) \text{ period}_2}{\sum_{i=1}^{m} [(Q_i^I) \text{ period}_1} & \times & \dfrac{(p_i^I) \text{ period}_2]}{(p_i^I) \text{ period}_1]} & & \dfrac{\text{TC period}_2}{\text{TC period}_1} \\
\parallel & & \parallel & & \parallel \\
\Delta \text{ resource quantity} & \times & \Delta \text{ resource costs (prices)} & = & \Delta \text{ cost} \\
\text{Column 1} & & \text{Column 2} & & \text{Column 3} \\
\text{Productivity} & \times & \text{“Price Recovery”} & = & \text{Profitability}
\end{array}$$

**Figure 5.2 Productivity, Price Recovery, Profitability Relationship.**

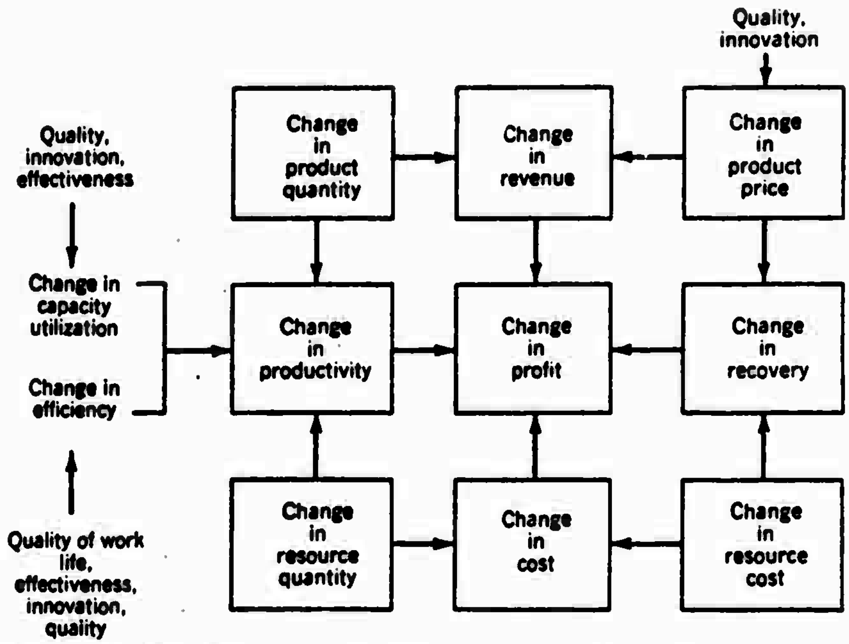



**Figure 5.3 Basic Factors and Interrelationships Contributing to Performance** (Adapted from B. J. van Loggerenberg and S. J. Cucchiaro, "Productivity Measurement and the Bottom Line," *National Productivity Review*, Winter 1981–82)

index." The price recovery index is a change in output prices over a change in resource costs (prices). Column 3 reflects the profitability index, a change in revenues over a change in costs. Note that if all other factors are held constant, namely prices and costs, a positive change in the productivity index will cause or translate into a positive change in profits. Similarly, if quantities are held constant and the price recovery index is positive (output prices increase at a faster rate than resource costs), then profits, at least in the short run, will be positive. Figure 5.3, adapted from van Loggerenberg and Cucchiaro, is another representation of these relationships.

The MFPMM reflects an attempt to add to and enhance conventional profit analysis represented by Column 3. The ability to evaluate profitability changes in terms of where they come from and how they were caused is increasingly coming to be viewed as an important control system element. Similar to redesigning the control panel for an aircraft, we are beginning to see management in the United States reevaluate the instruments, dials, knobs, and controls in the control system for organizations.

## *Description of the MFPMM*

Table 5.3 depicts the format for the MFPMM. The easiest way to describe the model is to work through the format with an example, moving from left to right

**Table 5.3 Multiple Productivity Measurement Model Format (VPI/VPC Version MFPMM)**

| | PERIOD 1 | | | PERIOD 2 | | | WEIGHTED CHANGE RATIOS | | | COST/REVENUE RATIOS | | PRODUCTIVITY RATIOS | | WEIGHTED PERFORMANCE INDEXES | | | DOLLAR EFFECTS ON PROFITS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | CHANGE IN PRODUCTIVITY | CHANGE IN PRICE RECOVERY | CHANGE IN PROFITABILITY | CHANGE IN PRODUCTIVITY | CHANGE IN PRICE RECOVERY | CHANGE IN PROFITABILITY |
| | QUANTITY $Q_{i1}$ | PRICE $P_{i1}$ | VALUE $(Q_{i1})(P_{i1})$ | QUANTITY $Q_{i2}$ | PRICE $P_{i2}$ | VALUE $(Q_{i2})(P_{i2})$ | $\frac{Q_2P_1}{Q_1P_1}$ | $\frac{Q_2P_2}{Q_2P_1}$ | $\frac{Q_2P_2}{Q_1P_1}$ | $\frac{I_{i1}}{\Sigma(Q_{i1})(P_{i1})}$ | $\frac{I_{i2}}{\Sigma(Q_{i2})(P_{i2})}$ | PERIOD 1 | PERIOD 2 | (7/7) | (8/8) | (9/9) | | | |
| OUTPUT(S) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| $O_{i,1\ldots n}$ | | | | | | | | | | | | | | | | | | | |
| $\sum_{i=1}^{n} O_i$ | | | | | | | | | | | | | | | | | | | |
| INPUT(S) $I_{ij}$ LABOR $I_{il}$ | | | | | | | | | | | | | | | | | | | |
| $\sum I_{il}$ | | | | | | | | | | | | | | | | | | | |
| MATERIAL $I_{im}$ | | | | | | | | | | | | | | | | | | | |
| $\sum I_{im}$ | | | | | | | | | | | | | | | | | | | |
| ENERGY $I_{ie}$ | | | | | | | | | | | | | | | | | | | |
| $\sum I_{ie}$ | | | | | | | | | | | | | | | | | | | |
| INVESTMENT $I_{ic}$ | | | | | | | | | | | | | | | | | | | |
| $\sum I_{ic}$ | | | | | | | | | | | | | | | | | | | |
| EXPENSES $I_{ix}$ | | | | | | | | | | | | | | | | | | | |
| $\sum I_{ix}$ | | | | | | | | | | | | | | | | | | | |
| ETC | | | | | | | | | | | | | | | | | | | |
| TOTAL INPUTS $\sum I_{ij}$ | | | | | | | | | | | | | | | | | | | |
| [illegible] | | | | | | | | | | | | | | | | | | | |

or from Column 1 to Column 19. For the purpose of instructional clarity, a simple example involving a fiberglass boat manufacturer is utilized to explain and "teach"the workings of MFPMM.

## *Columns 1–6*

The first six columns of the MFPMM are data input. Column 1 represents quantities of outputs the organizational system produced and/or sold and quantities of input resources consumed in order to produce those outputs for period 1. As mentioned previously, period 1 in this model will be designated as a base period. Selection of a base period is primarily a matter of selecting a representative period in time against which you wish to compare current period performance. It might be a period of time in 1967, which just happens to be the base year utilized in the consumer price index. Or it might be a unique period in time representative of current business conditions. The base period designation can be "standards" or even simply last period. However, note that if one selects the last period as the base period and hence allows the base period to change each time the current period moves ahead, then the built-in indexing mechanism in the model is negated. In such a case, an external indexing mechanism will have to be imposed. This involves utilizing a published index, such as the producers price index or the GNP index. For more detail on indexing, refer to Anderson, Sweeney, and Williams (1981) and American Productivity Center (1978).

Recall also that the organizational system boundaries or unit of analysis for this model are flexible. A productivity process modeling exercise should precede any attempted development of an application of the MFPMM. This will ensure accurate definition of unit of analysis, inputs, outputs, and outcomes. Another parameter to be determined prior to application of this model is the length of the analysis period. Depending on decision-maker needs and interests, data availability, product cycle time, and so forth, the length might be almost any period of time (weekly, monthly, quarterly, semiannually, annually). When determining the length of the period, keep in mind your data collection needs and data matching requirements. The goal is to match outputs produced during a given period to the input resources utilized during that same period in time.

So, Column 1 represents quantities of outputs produced during the base period and quantities of inputs utilized to produce those outputs during the same base period. Table 5.4 depicts data for the base period of our boat company example. Note that in period 1 (base period) the company produced 50 Boat *A*s and 30 Boat *B*s, and utilized 320 units (in this case, hours) of management labor, 800 units (hours) of fiberglass labor, 1120 units (hours) of assembly labor, 2200 units of fiberglass, 750 units of wood, 8000 units (in this case, KWHs) of electricity, and 100 units (in this case, MCF) of gas. Note also that the scale or units utilized for outputs and inputs is a decision that can be made by the analyst. In addition, the number and class of categories, types (subcategories), and levels (sub-subcategories) in inputs and outputs (the rows in the model) is a decision that can

**Table 5.4 LINPRIM Boat Company Example (VPI/VPC Version MFPMM): Period 1 (Columns 1–6)**

| | PERIOD 1 | | | PERIOD 2 | | |
|---|---|---|---|---|---|---|
| | (1) QUANTITY | (2) PRICE | (3) VALUE | (4) QUANTITY | (5) PRICE | (6) VALUE |
| BOAT A | 50.0 | 5000.00 | 250000.00 | 70.0 | 5500.00 | 385000.00 |
| BOAT B | 30.0 | 10000.00 | 300000.00 | 35.0 | 12000.00 | 420000.00 |
| TOTAL OUTPUTS | | | 550000.00 | | | 805000.00 |
| LABOR MANAGEMENT | 320.0 | 20.00 | 6400.00 | 304.0 | 22.00 | 6688.00 |
| LABOR GLASS | 800.0 | 8.00 | 6400.00 | 760.0 | 9.00 | 6840.00 |
| LABOR ASSEMBLY | 1120.0 | 6.00 | 6720.00 | 1064.0 | 7.00 | 7448.00 |
| TOTAL LABOR | | | 19520.00 | | | 20976.00 |
| FIBERGLASS | 2200.0 | 50.00 | 110000.00 | 3000.0 | 85.00 | 255000.00 |
| WOOD | 750.0 | 3.00 | 2250.00 | 1000.0 | 3.00 | 3000.00 |
| TOTAL MATERIALS | | | 112250.00 | | | 258000.00 |
| ELECTRICITY | 8000.0 | 0.10 | 800.00 | 8200.0 | 0.10 | 820.00 |
| NATURAL GAS | 100.0 | 4.00 | 400.00 | 90.0 | 4.00 | 360.00 |
| TOTAL ENERGY | | | 1200.00 | | | 1180.00 |
| TOTAL INPUTS | | | 132970.00 | | | 280156.00 |

be made by either the analyst, decision maker(s), or other users of the model. For example, one could break out, by level, management labor (president, supervisor, plant manager, and so forth). The model will accommodate at least three levels (class, type, and level) of output and input. Since the model is computerized, it can handle, depending on how it is programmed, almost any number of rows. For example, the VPI/VPC version of the model for a HP3000 system is programmed to accept up to 100 row elements for each category (output, labor, energy, materials). Minicomputer programs of the model, such as on the IBM PC with 126K storage, have capacity for slightly more than 50 total row elements.

Column 2 represents the unit price for outputs and unit cost for inputs during period 1 (base period). From Table 5.4 you can see that Boat *A* sold for $5000, and Boat *B* sold for $10,000; management labor cost $20.00 per unit (hour); fiberglass labor cost $8.00 per unit (hour); assembly labor cost $6.00 per unit (hour); fiberglass cost $50.00 per unit; wood cost $3.00 per unit; electricity cost $.10 per unit (KWH); and gas cost $4.00 per unit (MCF). Note that since the analyst or user of the model can define the unit of measurement to be utilized for each output and input, the unit price and cost is also controllable. For instance, labor cost can reflect base salary, or wage rate plus bonuses or benefit calculations. The only requirement is that the unit cost remain consistent with the units of quantity.

Column 3 reflects the value (quantity × price) for each row element (outputs and inputs). Therefore, column 3 represents revenues for outputs and costs for inputs. This column is calculated automatically by the programmed version of this model. So, from Table 5.4 you can see that this company had revenues of $250,000 from sales of Boat *A*s and $300,000 from sales of Boat *B*s for a total revenue figure of $550,000; at the same time, cost for management labor was $6400; fiberglass labor, $6400; assembly labor $6720; fiberglass, $110,000; wood, $2250; electricity, $800; and gas, $400. Again, Column 3 is automatically calculated in the programmed version of this model.

Columns 4–6 are the same as columns 1–3 except that they are data for period 2 or the current period. Again, columns 4 and 5 are the data input requirements and column 6 is simply column 4 × column 5. From Table 5.4 you can see the following:

1. Boat *A* production went from 50 in the base period to 70 in current period; the price for Boat *A* went from $5000 in period 1 to $5500 current period.
2. The company utilized 16 less units (hours) of management labor but increased the cost for that category of labor from $20.00 to $22.00.
3. Fiberglass utilization increased by 800 units, and the unit cost rose from $50.00 to $85.00.

Interpretation of other changes should by now be evident and self-explanatory.

These first six columns of the MFPMM, in particular Columns 1, 2, 4, and 5, reflect data input required to "run" the model. Data availability appears not to be a critical roadblock to successful implementation of this model. Experience suggests that the basic data required to run this model are typically available from most accounting or comptroller departments. Many decisions and finer points to the actual development of an application of this model could be discussed now. However, it may be more effective to continue this tutorial on this simple example and reserve discussion of finer points until later in this Chapter.

## *Columns 7–9*

The next three columns in the MFPMM are titled "Weighted Change Ratios." The basic purpose of these columns and, in particular, the formula calculations is to determine:

*Column 7:* Price-weighted and base period price indexed changes in quantities. Essentially, Column 7 partials out or holds constant the effect of prices and just examines the price-weighted changes in quantities of outputs and inputs. (See Figure 5.4 for the formula for Column 7.)

*Column 8:* Quantity-weighted and current period indexed changes in unit prices and unit costs. Essentially, Column 8 partials out or holds constant the changes in quantities of outputs and inputs and just examines the changes in unit prices and unit costs from period 1 to period 2. (See Figure 5.4 for the formula for Column 8.)

$$\text{Column 7: } \frac{\sum_{i=1}^{n} (Q_{i2})(p_{i1})}{\sum_{i=1}^{n} (Q_{i1})(p_{i1})}$$

$$\text{Column 8: } \frac{\sum_{i=1}^{n} (Q_{i2})(p_{i2})}{\sum_{i=1}^{n} (Q_{i2})(p_{i1})}$$

$$\text{Column 9: } \frac{\sum_{i=1}^{n} (Q_{i2})(p_{i2})}{\sum_{i=1}^{n} (Q_{i1})(p_{i1})} \text{ or Column 7} \times \text{Column 8}$$

**Figure 5.4 Weighted-Change Ratio Formulas for Outputs and Inputs**

*Column 9:* Examines the simultaneous impact of changes in price and quantity from period 1 to period 2 for each row in the model. (See Figure 5.4 for the formula for Column 9.)

From Column 7 (Table 5.5) it can be seen that

1. In period 2, 40 percent more Boat *A*s were produced than in period 1.

$$\frac{Q_2P_1^*}{Q_1P_1} = \frac{70(5000)}{50(5000)} = 1.40$$

2. In period 2, 16.67 percent more Boat *B*s were produced than in period 1.

$$\frac{35(10000)}{30(10000)} = 1.1667$$

3. In period 2, 27.27 percent more boats of types *A* and *B* were produced.

$$\frac{\Sigma Q_2P_1^*}{\Sigma Q_1P_1} = \frac{70(5000) + 35(10000)}{50(5000) + 30(10000)} = 1.2727$$

4. In period 2, 5 percent less labor was utilized than in period 1.

$$\frac{304(20) + 760(8) + 1064(6)}{320(20) + 800(8) + 1120(6)} = 0.95$$

*Shorthand formula notation.

**Table 5.5 LINPRIM Boat Company Example (VPI/VPC Version MFPMM): Columns 7–11**

| | WEIGHTED CHANGE RATIOS | | | COST/REVENUE RATIOS | | PRODUCTIVITY RATIOS | |
|---|---|---|---|---|---|---|---|
| | (7) QUANTITY | (8) PRICE | (9) VALUE | (10) PERIOD 1 | (11) PERIOD 2 | (12) PERIOD 1 | (13) PERIOD 2 |
| BOAT A | 1.4000 | 1.1000 | 1.540 | | | | |
| BOAT B | 1.1667 | 1.2000 | 1.400 | | | | |
| TOTAL OUTPUTS | 1.2727 | 1.1500 | 1.464 | | | | |
| LABOR MANAGEMENT | 0.9500 | 1.1000 | 1.045 | 0.0116 | 0.0083 | 85.94 | 115.13 |
| LABOR GLASS | 0.9500 | 1.1250 | 1.069 | 0.0116 | 0.0085 | 85.94 | 115.13 |
| LABOR ASSEMBLY | 0.9500 | 1.1667 | 1.108 | 0.0122 | 0.0093 | 81.85 | 109.65 |
| TOTAL LABOR | 0.9500 | 1.1311 | 1.075 | 0.0355 | 0.0261 | 28.18 | 37.75 |
| FIBERGLASS | 1.3636 | 1.7000 | 2.318 | 0.2000 | 0.3168 | 5.00 | 4.67 |
| WOOD | 1.3333 | 1.0000 | 1.333 | 0.0041 | 0.0037 | 244.44 | 233.33 |
| TOTAL MATERIALS | 1.3630 | 1.6863 | 2.298 | 0.2041 | 0.3205 | 4.90 | 4.58 |
| ELECTRICITY | 1.0250 | 1.0000 | 1.025 | 0.0015 | 0.0010 | 687.50 | 853.66 |
| NATURAL GAS | 0.9000 | 1.0000 | 0.900 | 0.0007 | 0.0004 | 1375.00 | 1944.44 |
| TOTAL ENERGY | 0.9833 | 1.0000 | 0.983 | 0.0022 | 0.0015 | 458.33 | 593.22 |
| TOTAL INPUTS | 1.2990 | 1.6220 | 2.107 | 0.2418 | 0.3480 | 4.14 | 4.05 |

5. In period 2, 36.36 percent more fiberglass was utilized than in period 1.

$$\frac{Q_2P_1^*}{Q_1P_1} = \frac{3000(50)}{2200(50)} = 1.3636$$

6. In period 2, 33.33 percent more wood was utilized than in period 1.

$$\frac{1000(3)}{750(3)} = 1.3333$$

7. In period 2, 36.3 percent more materials were utilized than in period 1.

$$\frac{3000(50) + 1000(3)}{2200(50) + 750(3)} = 1.3630$$

*Shorthand formula notation.

8. Total price-weighted and indexed change in inputs utilization was 29.90 percent.

$$\frac{304(20) + 760(8) + 1064(6) + 3000(50) + 1000(3) + 8200(.10) + 90(4)}{320(20) + 800(8) + 1120(6) + 2200(50) + 750(3) + 8000(.10) + 100(4)}$$

Hence, Column 7 simply tells us the rate of price-weighted quantity change with prices and costs held constant at period 1 levels.

From Column 8 it can be seen that

1. The prices of Boat $A$ went up 10 percent.

$$\frac{Q_2P_2^*}{Q_2P_1} = \frac{70(5500)}{70(5000)} = 1.10$$

2. The quantity-weighted average price change for Boats $A$ and $B$ was 15 percent.

$$\frac{\Sigma Q_2P_2^*}{\Sigma Q_2P_1} = \frac{70(5500) + 35(12000)}{70(5000) + 35(10000)} = 1.15$$

3. Management labor unit cost increased 10 percent

$$\frac{304(22)}{304(20)} = 1.10$$

4. Quantity-weighted average cost increase for labor was 13.11 percent.

$$\frac{304(22) + 760(9) + 1064(7)}{304(20) + 760(8) + 1064(6)} = 1.1311$$

5. Fiberglass unit cost increased 70 percent

$$\frac{3000(85)}{3000(50)} = 1.70$$

*Shorthand formula notation.

6. Quantity-weighted average cost increase for materials was 68.63 percent.

$$\frac{3000(85) + 1000(3)}{3000(50) + 1000(3)} = 1.6863$$

7. There were no changes in the price of gas or electricity.

$$\frac{8200(.10) + 90(4)}{8200(.10) + 90(4)} = 1.00$$

8. Total quantity-weighted change in input costs was 62.20 percent.

$$\frac{304(22) + 760(9) + 1064(7) + 3000(85) + 1000(3) + 8200(.10) + 90(4)}{304(20) + 760(8) + 1064(6) + 3000(50) + 1000(3) + 8200(.10) + 90(4)}$$

Hence, Column 8 simply indicates the rate of quantity-weighted price and cost change with quantities of outputs and inputs held constant at period 2 levels.

From Column 9 it can be seen that

1. Revenues from Boat *A* increased 54 percent.

$$\frac{Q_2P_2^*}{Q_1P_1} = \frac{70(5500)}{50(5000)} = 1.54$$

2. Combined impact on revenue change from period 1 to period 2 from both Boat *A* and Boat *B* was 46.36 percent.

$$\frac{\Sigma Q_2P_2^*}{\Sigma Q_1P_1} = \frac{70(5500) + 35(12000)}{50(5000) + 30(10000)} = 1.4636$$

3. Total labor cost increased 7.46 percent from period 1 to period 2.

$$\frac{304(22) + 760(9) + 1064(7)}{320(20) + 800(8) + 1120(6)} = 1.0746$$

*Shorthand formula notation.

4. Total input costs increased 110.69 percent.

$$\frac{304(22) + 760(9) + 1064(7) + 3000(85) + 1000(3) + 8000(.10) + 90(4)}{320(20) + 800(8) + 1120(6) + 2200(50) + 750(3) + 8000(.10) + 100(4)}$$

Hence, Column 9 simply indicates the rate of change of revenues and costs (simultaneous changes in prices, costs, and quantities of outputs and inputs).

## *Columns 10 and 11*

Columns 10 and 11 are labeled "Cost/Revenue Ratios." They indicate the ratio of input row elements for Columns 3 and 6. The formula for these columns appears in Figure 5.5. Note that Column 10 is the cost-to-revenue ratio for period 1 and Column 11 is the cost-to-revenue ratio for period 2.

From Column 10 one can observe that management labor costs (Column 3) represent 1.16 percent of total revenues in period 1 ($6400/$550,000). Similarly, total labor costs represent 3.55 percent of total revenues, fiberglass costs reflect 20 percent of total revenues, and total input costs reflect 24.18 percent of total revenues. Note that since this model is not attempting to be a total factor productivity measurement model, there is no way to tell directly whether the 75.82 percent of remaining revenues is all profits or consumed by other input resource costs not captured in this model. Note also that the information in these two columns will very likely be already available and familiar to most managers. Most managers are knowledgeable about certain cost categories as a percentage of either total costs, total revenues, or some other aggregate budget number.

The purpose of these two columns is not to provide new information but to integrate this information into the MFPMM so as to provide a manager with

$$\text{Column 10: } \frac{I\,ij_1}{\sum_{i=1}^{n}(O_{i1})(p_{i1})} = \frac{\text{Input elements, column 3}}{\text{Total, column 3}}$$

$$\text{Column 11: } \frac{I\,ij_2}{\sum_{i=1}^{n}(O_{i2})(p_{i2})} = \frac{\text{Input elements, column 6}}{\text{Total column 6}}$$

$$\text{Column 12: } \frac{\sum_{i=1}^{n}(O_{i1})(p_{i1})}{(I_{ij1})(p_{ij1})} = \frac{\text{Total, column 3}}{\text{Input elements, column 6}}$$

$$\text{Column 13: } \frac{\sum_{i=1}^{n}(O_{i2})(p_{i1})}{(I_{ij2})(p_{ij1})} = \frac{\text{Base period price weighted total, column 6}}{\text{Base period price weighted input elements, column 6}}$$

Figure 5.5 Cost/Revenue Ratio Formulas

insights as to where leverage exists. If Columns 10 and 11 are rank ordered, the manager can then invoke Pareto's Principle and make productivity improvement decisions, in terms of cost reduction, on the higher priority input resources. From this example one can easily see that a manager's leverage is with fiberglass and, in particular, with fiberglass prices.

From Column 11 it can be observed that labor costs are now (in period 2 or current period) 2.61 percent of revenues, a decrease from 3.55 percent in period 1. Fiberglass costs are now 31.68 percent of revenues, an increase from 20 percent. And total costs are now 34.8 percent of revenues, up from 24.18 percent.

## *Columns 12 and 13*

Columns 12 and 13 are titled "Productivity Ratios." Column 12 reflects the output-to-input ratios for period 1, while column 13 reflects the output-to-input ratios for period 2. This is a relatively new edition to this model and exists only on certain versions of the software for this particular productivity measurement technique. The formulas for these two columns appear in Figure 5.5.

## *Columns 14–16*

Columns 14–16 (Table 5.6) are titled "Weighted Performance Indexes." Column 14 reflects price-weighted productivity indexes. Column 15 represents quantity-

**Table 5.6 LINPRIM Boat Company Example (VPI/VPC Version MFPMM): Columns 14–19**

| | WEIGHTED PERFORMANCE INDEXES | | | DOLLAR EFFECTS ON PROFITS | | |
|---|---|---|---|---|---|---|
| | (14) | (15) | (16) | (17) | (18) | (19) |
| | CHANGE IN | | | CHANGE IN PRODUC-TIVITY | CHANGE IN PRICE RECOVERY | CHANGE IN PROFIT-ABILITY |
| | PRODUC-TIVITY | PRICE RECVRY | PROFIT-ABILITY | | | |
| BOAT A | | | | | | |
| BOAT B | | | | | | |
| TOTAL OUTPUTS | | | | | | |
| LABOR MANAGEMENT | 1.340 | 1.045 | 1.401 | 2065.45 | 613.82 | 2679.27 |
| LABOR GLASS | 1.340 | 1.022 | 1.369 | 2065.45 | 461.82 | 2527.27 |
| LABOR ASSEMBLY | 1.340 | 0.986 | 1.321 | 2168.73 | 218.91 | 2387.64 |
| TOTAL LABOR | 1.340 | 1.017 | 1.362 | 6299.64 | 1294.54 | 7594.18 |
| FIBERGLASS | 0.933 | 0.676 | 0.631 | -10000.00 | -84000.00 | 94000.00 |
| WOOD | 0.955 | 1.150 | 1.098 | -136.36 | 429.55 | 297.18 |
| TOTAL MATERIALS | 0.934 | 0.682 | 0.637 | -10136.38 | -83570.44 | -93706.81 |
| ELECTRICITY | 1.242 | 1.150 | 1.428 | 198.18 | 152.73 | 350.91 |
| NATURAL GAS | 1.414 | 1.150 | 1.626 | 149.09 | 76.36 | 225.45 |
| TOTAL ENERGY | 1.274 | 1.150 | 1.480 | 347.27 | 229.09 | 576.36 |
| TOTAL INPUTS | 0.980 | 0.709 | 0.695 | -3489.45 | -82046.81 | [illegible] |

weighted price recovery indexes. And Column 16 depicts profitability indexes. The formulas for these three columns appear in Figure 5.6. Note that there are no entries for the cells corresponding to the output row elements. This is because Columns 14–16 are now calculating output over input indexes, or changes in performance ratios, from period 1 to period 2. The essence of the MFPMM appears in Columns 12–19.

As discussed in Chapter 2, there are at least four generic types of productivity "measures": (1) partial factor, static ratio; (2) total factor, static ratio; (3) partial factor, dynamic index; and (4) total factor, dynamic index. Recall that a dynamic productivity index is essentially a productivity ratio at one period in time, say, period 2 (current period), over that same productivity ratio at a previous period in time, say, period 1 (base period). Columns 14–16 calculate and depict dynamic *performance* indexes. Column 14 calculates and depicts dynamic *productivity* indexes. Figure 5.7 conceptually depicts what the MFPMM is doing.

In Figure 5.7, formulas and development of static productivity ratios are depicted. We take a snapshot of the organizational system for a given period of time and place some or all of the outputs in the numerator and one, some, or all of the inputs in the denominator. For a decoupled, disaggregated system, such as the NPMM, we do not necessarily need to use indexed prices and costs as a common denominator. For an aggregated system, such as the MFPMM, indexed prices and costs are necessary.

*Column 14:*

$$\frac{\left.\dfrac{\sum_{i=1}^{n}(O_{i2})(p_{i1})}{\sum_{i=1}^{n}(O_{i1})(p_{i1})}\right.}{\dfrac{(Iij_2)(p_{i1})}{(Iij_1)(p_{i1})}} \qquad \frac{=\ \text{Column 7 for total outputs}}{=\ \text{Column 7 for each individual input}} \qquad \text{Productivity}$$

*Column 15:*

Column 14/Column 12

or

$$\frac{\left.\dfrac{\sum_{i=1}^{n}(O_{i2})(p_{i2})}{\sum_{i=1}^{n}(O_{i2})(p_{i1})}\right.}{\dfrac{(Iij_2)(p_{i2})}{(Iij_2)(p_{i1})}} \qquad \frac{=\ \text{Column 8 for total outputs}}{=\ \text{Column 8 for each input}} \qquad \text{Price recovery}$$

*Column 16:*

$$\frac{\left.\dfrac{\sum_{i=1}^{n}(O_{i2})(p_{i2})}{\sum_{i=1}^{n}(O_{i1})(p_{i1})}\right.}{\dfrac{(Iij_2)(p_{i2})}{(Iij_1)(p_{i1})}} \qquad \frac{=\ \text{Column 9 for total outputs}}{=\ \text{Column 9 for each input}} \qquad \text{Profitability}$$

**Figure 5.6 Weighted Performance Indexes**

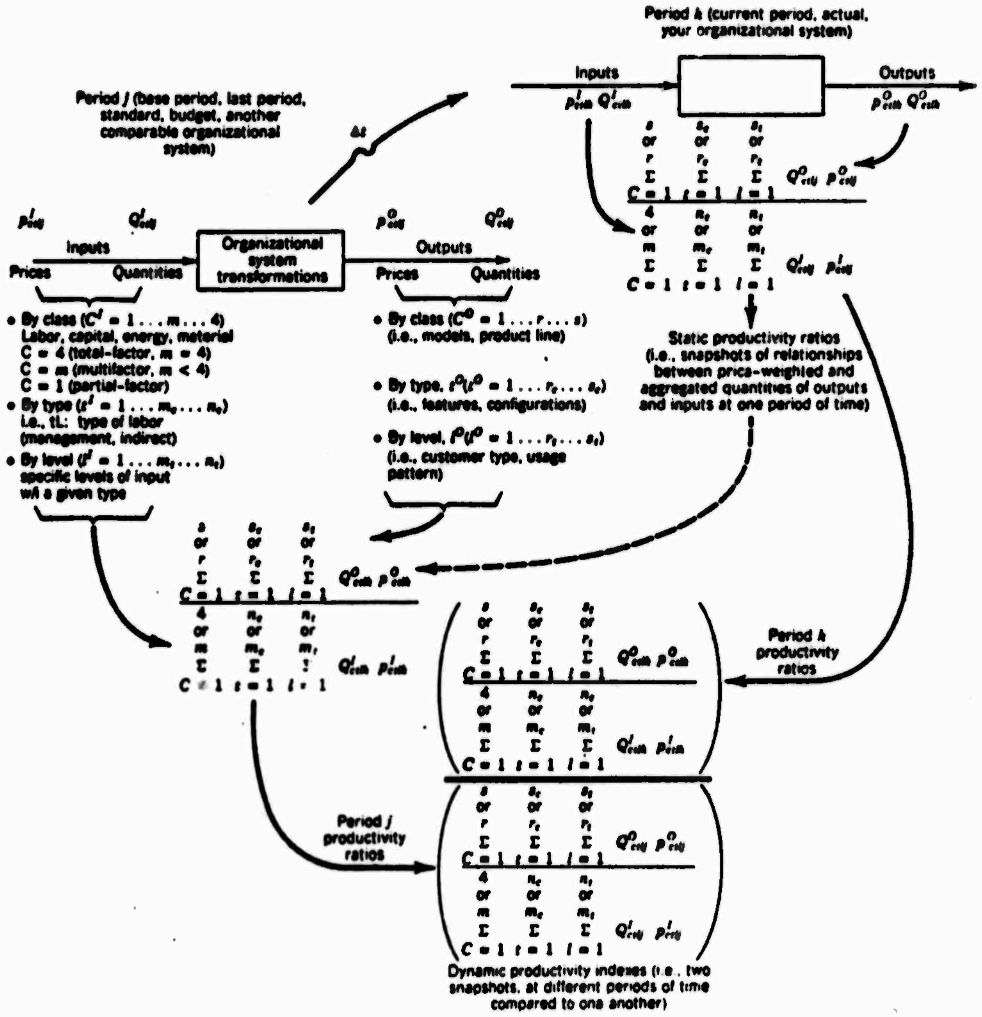



**Figure 5.7 Price-Weighted and Aggregated Multifactor Productivity Measurement Model**

Figure 5.7 also depicts formulas and development of dynamic productivity indexes. A snapshot of the organizational system's partial, multi-, and perhaps even total static productivity ratio is developed for period *k* (period 2, current period). An equivalent snapshot of the organizational system's partial, multi-, or perhaps even total static productivity ratio is developed for period *j* (period 1, base period, budget, standards, another comparable system, and so forth). The productivity ratios for period *k* (period 2 or current period) are then divided by the productivity ratios for period *j* (period 1 or base period). The resultant formulation is highlighted in Figure 5.7, and it is this calculation that is depicted in Column 14 of the MFPMM.

From Column 14 the following observations can be made:

1. Labor productivity increased by 34 percent.

$$\frac{\text{Column 7 for total outputs} = 1.2727}{\text{Column 7 for total inputs} = .95} = 1.34$$

(Note that Column 7 is the price-weighted changes in quantities for outputs and inputs. As an exercise, see question 13 at the end of this chapter to convince yourself that

$$\frac{O}{I} = \frac{Q_2^O/Q_1^O}{Q_2^I/Q_1^I} = \frac{Q_2^O/Q_2^I}{Q_1^O/Q_1^I}$$

This tells us that price-weighted change in outputs from period 1 to period 2 went up 27.27 percent while labor input went down 5 percent creating a corresponding gain in productivity of 34 percent.

2. Materials productivity decreased 7 percent.

$$\frac{\text{Column 7 for total outputs} = 1.2727}{\text{Column 7 for total materials} = 1.363} = 0.93$$

3. Total inputs productivity declined by 2 percent. Again, total price-weighted and indexed outputs from this company increased by 27.27 percent, while total price-weighted and indexed input quantities increased by 29.9 percent. Hence, 1.2727/1.299 = 0.98 and the calculated 2 percent decline in productivity for all inputs measured in this model formulation.

Column 15 depicts rates of change for quantity-weighted and indexed prices over costs. It reflects rate of price increases in relation to the rate of cost increases. In a sense it reflects the degree to which the organizational system was able to increase its price in relation to elemental input costs. It is simply termed price recovery.

From Column 15 it can be observed that

1. Price recovery for management labor was up 5 percent.

$$\frac{\text{Column 8 for total outputs} = 1.15}{\text{Column 8 for management labor} = 1.10} = 1.045$$

This indicates that the organization was able to raise prices approximately 5 percent faster than management unit prices (costs) increased.

2. Price for fiberglass increased approximately 32 percent faster than management was able to raise the prices of boats.

$$\frac{\text{Column 8 for total outputs} = 1.15}{\text{Column 8 for fiberglass input} = 1.7} = 0.676$$

3. On the whole, price recovery fell off by 29 percent.

$$\frac{\text{Column 8 for total outputs} = 1.15}{\text{Column 8 for total inputs} = 1.622} = 0.71$$

Changes in output prices were 71 percent of the changes in input costs. The company was not able or did not (for whatever reason) raise prices fast enough to compensate for increases in costs. (Note: Fiberglass price under-recovery was the major source of the relatively poor price recovery ratio of .71.)

Column 16 indicates profitability indexes, which reflect rates of change for simultaneous changes in price and quantity. The simplest way to think about Column 16 is that it is revenues/costs (a measure of profitability) for period 2 divided by revenues/costs for period 1. Hence, Column 16 is in reality a profitability index.

From Column 16 it can be seen that labor contributed to a 36 percent increase in profitability from period 1 to period 2. That is, revenues went up 46.36 percent from period 1 to period 2 (Column 9 for total outputs), while total labor costs increased by 7.46 percent (Column 9 for total labor) creating a 36 percent (1.4636/1.0746 = 1.3619) labor relative increase in profitability from period 1 to period 2. Materials created a period 1 to period 2 relative drain on profitability of 36 percent. Revenues changed at a rate of 46.36 percent, while material costs increased at a rate of 129.84 percent. Note that most of this drain on potential profits, which could have been achieved from the 46.36 percent increase in revenues, was caused by the 131.82 percent increase in fiberglass costs (both increased unit cost and increased quantity usage).

Overall, Column 16 depicts a 31 percent decline in potential profitability. This company was 31 percent less profitable in period 2 than it was in period 1. The company may well have made profits, but it could have made 31 percent more profits had certain price under-recovery situations not occurred. It should by now be clear that a number in Column 14, 15, or 16 that is greater than 1.00 reflects a positive change and a number less than 1.00 reflects a negative change. Therefore, our overall evaluation of this particular organization's productivity, price recovery, and profitability performance on a period 1 to period 2 basis is not favorable. In particular, management or an analyst could be concerned about fiberglass cost recovery.

## Columns 17–19

Columns 17–19 reflect the dollar equivalence of corresponding cells in Columns 14–16. In other words, these columns indicate what impact an increase in productivity (Column 17) or price recovery (Column 18) has on profits. The total impact on profits from productivity and price recovery is indicated in Column 19. The formulas for these columns appear in Figure 5.8. From these columns we see the following.

1. *Column 17:* Management labor productivity contributed $2065.45 to profits from period 1 to period 2.

$$(1.2727 - .95)\$6400 = \$2065$$

*Column 18:* The model does not directly calculate Column 18, effect of price recovery on profits. Column 18 values are calculated by subtracting Column 17 values from Column 19 values. In other words, Column 17 + Column 18 = Column 19.

*Column 19:* Management labor contributed positively to profits between period 1 and period 2 to the tune of $2679. About $2065 came from productivity gains and $613 came from price recovery gains.

$$(1.4636 - 1.045)\$6400 = \$2679$$

Column 17:

$$\left[\begin{array}{c}(lij_1)(P_{i1})\\ \text{or}\\ \text{Column 3}\\ \text{for each}\\ \text{corresponding}\\ \text{input}\end{array}\right]\left[\left(\frac{\sum_{i=1}^{n}(Q_{i2})(p_{i1})}{\sum_{i=1}^{n}(Q_{i1})(p_{i1})}\ \text{or}\ \begin{array}{c}\text{Column 7}\\ \text{for total}\\ \text{outputs}\end{array}\right)-\left(\frac{(lij_2)(p_{i1})}{(lij_1)(p_{i1})}\ \text{or}\ \begin{array}{c}\text{Column 7}\\ \text{for each}\\ \text{input}\end{array}\right)\right]$$

Column 18: Column 19 − Column 17

Column 19:

$$\left[\begin{array}{c}(lij_1)(p_{i1})\\ \text{or}\\ \text{Column 3}\\ \text{for each}\\ \text{corresponding}\\ \text{input}\end{array}\right]\left[\left(\frac{\sum_{i=1}^{n}(Q_{i2})(p_{i2})}{\sum_{i=1}^{n}(Q_{i1})(p_{i1})}\ \text{or}\ \begin{array}{c}\text{Column 9}\\ \text{for total}\\ \text{outputs}\end{array}\right)-\left(\frac{(lij_2)(p_{i2})}{(lij_1)(p_{i1})}\ \text{or}\ \begin{array}{c}\text{Column 9}\\ \text{for each}\\ \text{input}\end{array}\right)\right]$$

**Figure 5.8 Weighted Performance Indexes, Individual Effects on Profits**

## *MFPMM Simulation Routine: Decision Support System Developments*

Imagine the following setting in relation to the boat manufacturing company just presented. The president of the firm, his managers of purchasing, marketing, production, personnel, industrial engineering, quality control, and finance (comptroller), and a staff industrial engineer who is the company's productivity analyst are in a monthly planning meeting to discuss the performance of the company this past month. The productivity analyst has just presented a briefing summarizing the report just described to you in the last section. The productivity analyst has learned from past meetings with this group of upper-level managers that their tolerance for long complex briefings and reports is low. So, the analyst has worked hard to develop a simple yet effective set of graphics that succinctly summarize and depict the key data from the MFPMM. The analyst has learned that some of this group of managers feel more comfortable with raw data, tables, and figures while others prefer to see charts, graphs, and other pictorial-type representations of the MFPMM report. A few samples from the analyst's briefing materials are presented on the next several pages.

The analyst has assumed the role of facilitator for this session. Each manager is provided with a briefing package prior to this performance/productivity improvement planning session. This package includes the managers' own individualized summary graphics of the most recent MFPMM run, graphics such as the ones depicted in Figure 5.9, and the actual output in an appendix (if requested). In preparation for this monthly session, each manager reviews the MFPMM results in addition to any other performance measurement control

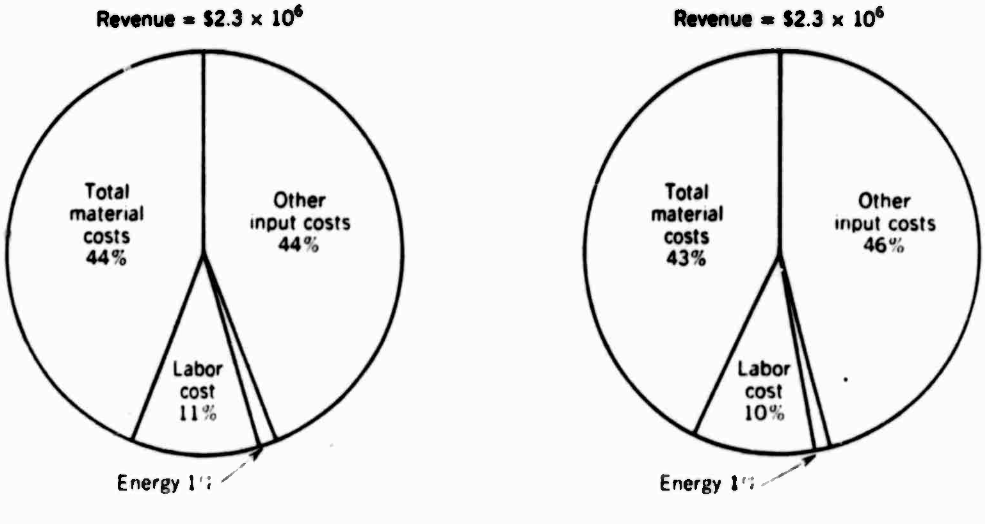



Figure 5.9a Input Costs as a Percentage of Revenue

2. *Total materials Column 19:* Low productivity in materials utilization created a drain on profits from period 1 to period 2 of −\$10,136. About \$10,000 of this decline came from low fiberglass productivity alone.

$$(1.2727 - 1.363)\$112{,}250 = -\$10{,}136$$

*Total materials Column 19:* Very poor price recovery on fiberglass and low productivity created a −\$93,706 drain on profits for this company from period 1 to period 2.

$$(1.4636 - 2.2984)\$112{,}250 = -\$93{,}706$$

This reflects the drain on profits caused by an inability to recover rising costs from period 1 to period 2. As one can see, the biggest source of lowered profits from period 1 to period 2 is this category.

3. Overall, this boat manufacturing company was \$85,536 less profitable in period 2 than in period 1 had nothing changed in the company. About \$82,047 of this decline in profits is attributable to relatively poor price recovery. And, as indicated, very poor fiberglass price recovery is the major source of this total decline in profits.

This completes the description and example for the MFPMM. There are obviously many fine details, application and implementation issues, and refinements that could be discussed. Some of these points will be dealt with in this section. However, at this point, the reader should have a good grasp of the basic character of the model. It is a relatively simple model and yet it has tremendous potential as an integrative decision support system. There are applications at the end of this chapter that can be utilized to develop more skill and a deeper understanding of how to interpret program output. Those desiring to purchase the model software can experiment with the model quite painlessly. You might even wish to collect data from a specific example of your own and run the program. Like any decision support system, the model itself is a critical but rather minor component of an application. Integrating the model into an existing control system, collecting the data, getting management to accept and feel comfortable with the system, and selling the system based on benefit-to-cost projects are all activities that actually play a more critical role in successful implementation of such a system.

In an attempt to improve the decision support capabilities of the model, staff at the Oklahoma Productivity Center and now at the Virginia Productivity Center have developed a simple simulation routine to allow management to project the impact of productivity improvement interventions on profits. This development is the focus of the discussion in the next section.

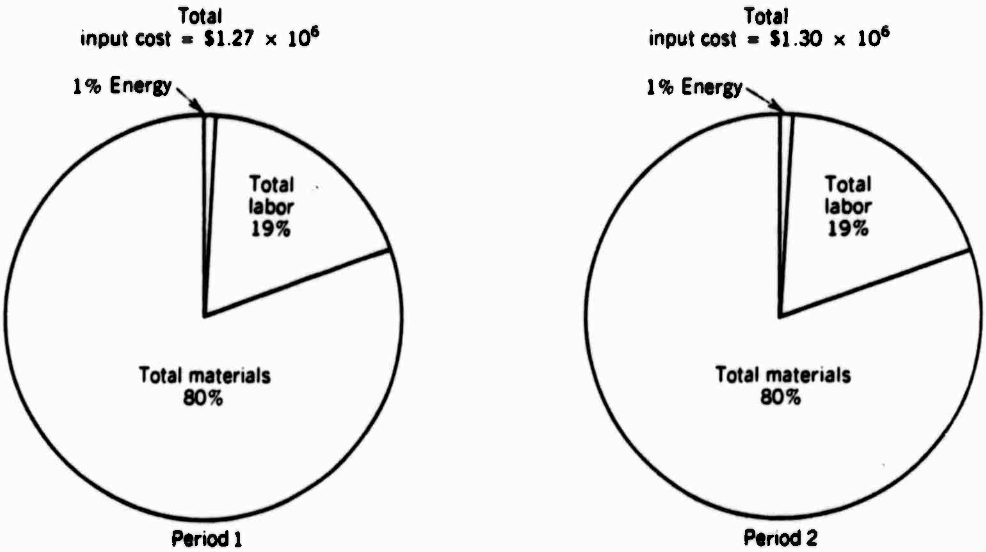



**Figure 5.9*b* Cost of Classes of Input as a Percentage of Cost of Measured Input**

system data the managers individually have access to (production, inventory, quality, scheduling, perso nel type reports/information systems, and so forth). Each manager is also expected to make projections for input and/or output changes he or she foresees taking place either independently of intervention on his or her part or with appropriate action on the management team's part.

Each manager then comes to this monthly performance/productivity improvement planning session with some or potentially all of the form indicated in Figure 5.10 completed. In the meeting itself, the productivity analyst starts out by making a short, general review briefing of the most recent MFPMM report. The president of the firm is allowed five minutes to express his overall perception of the company's performance from a strategic standpoint. Each manager is then given no more than five minutes to state his or her assessment of the company's performance in the previous month. Data other than that provided by the MFPMM are often presented, and graphics in the form of overheads or handouts are frequently utilized.

At the end of this briefing and review session, the analyst loads the MFPMM software onto the company's business computer. The MFPMM simulation routine is called up, and the forecast portion of this planning session begins. The MFPMM simulation routine allows management to develop "what if" scenarios with the model. The only data input required are three point estimates (pessimistic, most likely, optimistic) for specific input and/or output values. One, some, or all of the prices, costs, output quantities, or input quantities can be changed. The analyst and managers have the option of comparing period 2 (current or immediate past period) with period 3 (forecasted, projected period, next month), or period 1 (base period) with period 3. Recall that if the group decides to compare periods 2 and 3, then the model's built-in base period in-

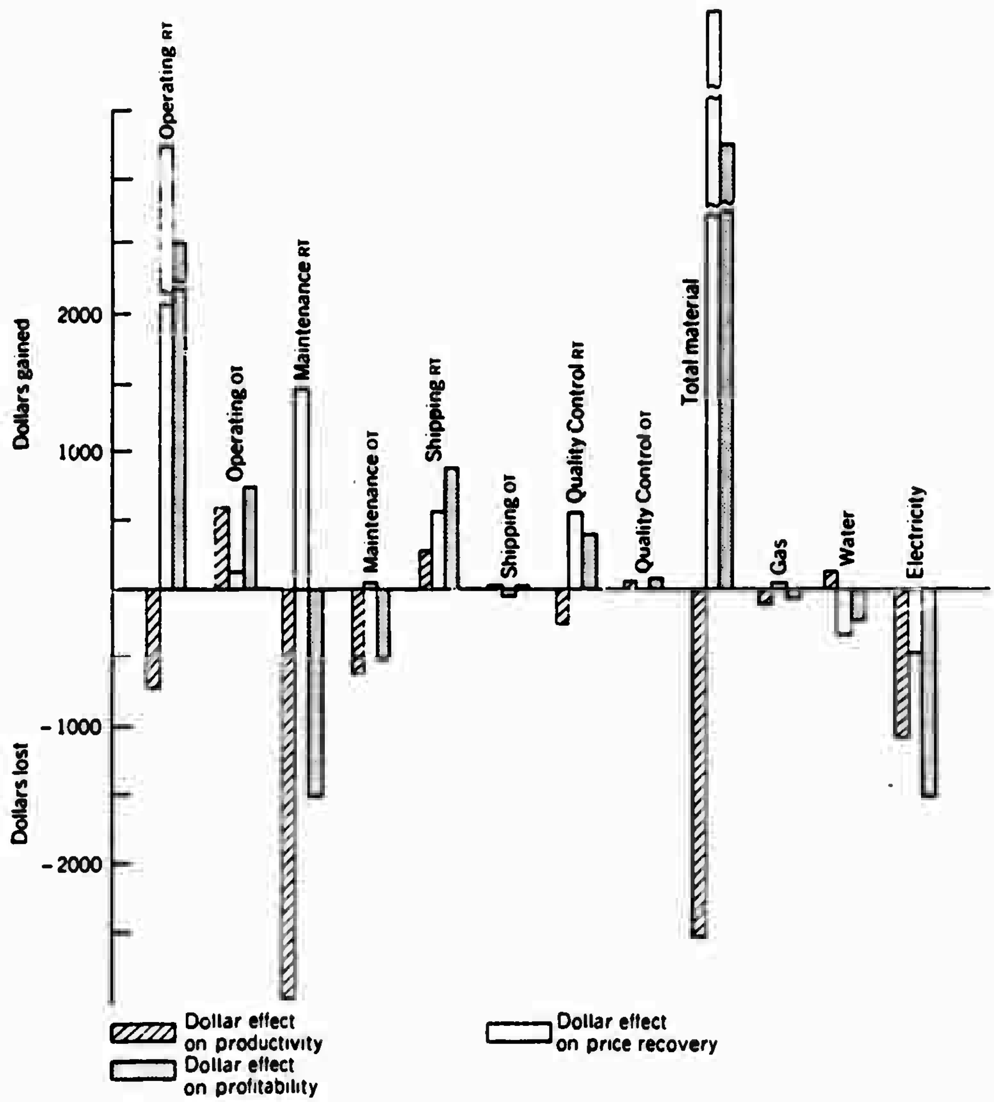



**Figure 5.9c Dollar Effect on Profitability, Productivity, and Price Recovery**

dexing process is negated. In this case, the analyst would have to externally or manually index all prices and costs to some constant value. If the group chooses to compare periods 3 and 1, then the MFPMM automatically removes the effect of inflation from the productivity analysis.

The next step in the simulation subroutine and planning process is to indicate a desired value for Column 19 for total inputs. The question is, what would the management group like the total effect on profits of their efforts to be at the end of the next month? The analyst asks them to indicate a desired value for the change in profitability for the following month. Recall that this value was

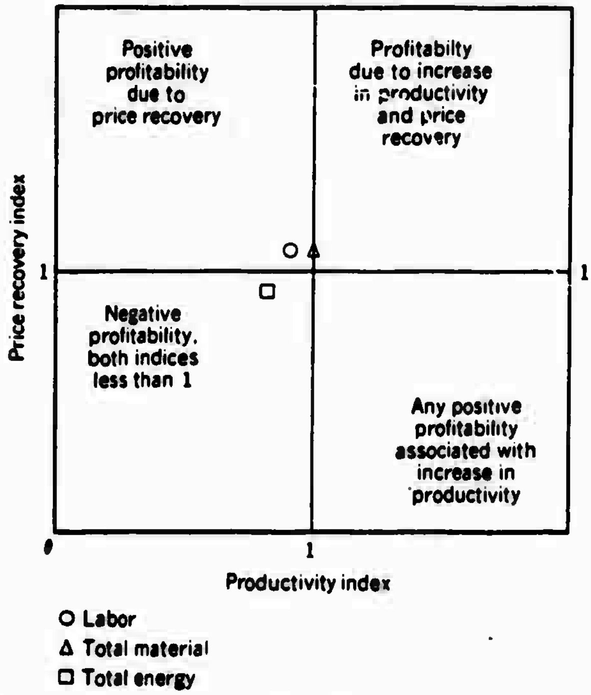
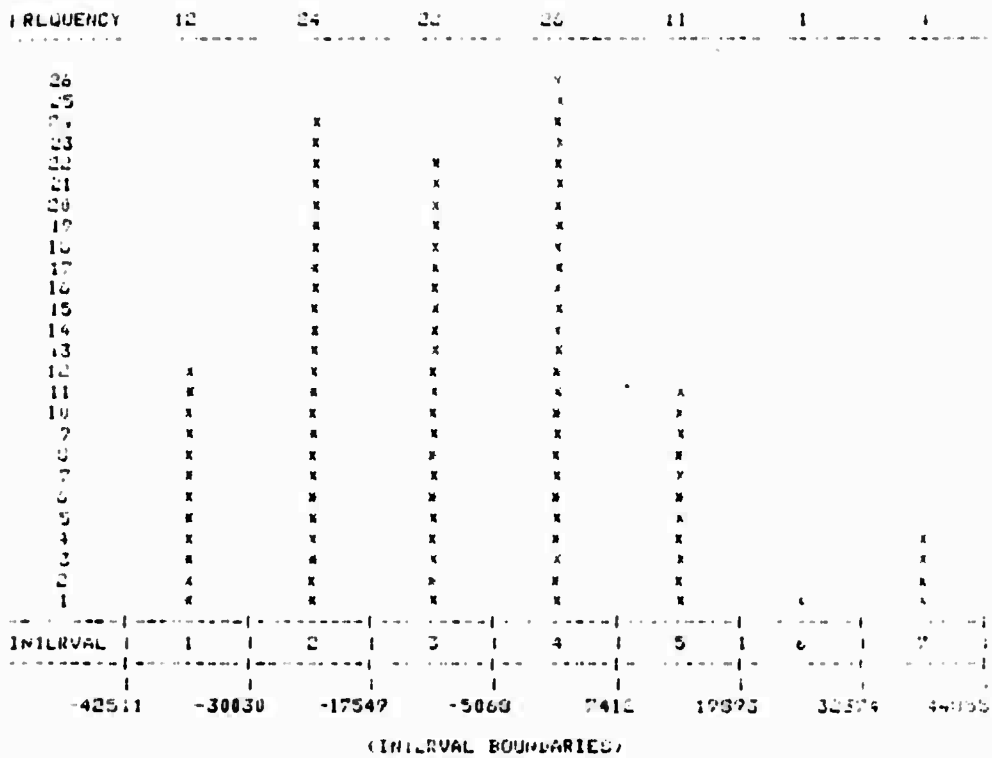


**Figure 5.9d** **Produc :vity, Price Recovery, and Profitability**

–$85,536 in period 2, or for the immediate past month. The management group agrees that given current economic and business conditions, they would be pleased if they could cause the number to go to $0.00. The analyst enters this decision into the computer.

The next step in the simulation subroutine and for this monthly session is to enter the three-point estimates for specific expected value changes for input quantities and costs, as well as for output quantities (in this case, sold boats) and prices. First, the projected changes for output quantities and prices are entered. There is much discussion among the managers of production, marketing, purchasing, industrial engineering, and quality control as to what the pessimistic, most likely, and optimistic values should be. Additional data from various sources are referred to for support of estimates. The analyst's job is one of keeping the session moving and striving for consensus. It is not critical that a unified estimate be arrived at. Several different scenarios can be developed, each based on a different set of assumptions. The simulation routine can be run for several scenarios and results can then be compared.

Next, labor projections are made in terms of staffing, workload scheduling and pay determinations. Again, three-point estimates are arrived at among relevant managers and entered by the analyst. The same process of making estimates is completed for materials, energy, and capital if it was included. A given scenario for this example is depicted in Tables 5.7a–d. This table presents the




PROBABILITY (FROM 100 SIMULATION RUNS) OF EQUALLING OR
EXCEEDING YOUR DESIRED VALUE OF 0 FOR TOTAL INPUTS
EFFECT ON CHANGE IN PROFITABILITY = .30

*(e)*

**Figure 5.9e Histogram Plot of Column 19 Values: Simulated Impact of Productivity Management Interventions on Profits**

entire simulation output comparing projected period 3 and base period 1. You may wish to compare this output with the output comparing periods 1 and 2 depicted in Tables 5.4–5.6. The simulation subroutine calculates expected values for all variables that were changed. Note when management changes or makes a three-point estimate for a given variable, that variable becomes stochastic or probabilistic in character. The triangular distribution is utilized to derive the expected values (Sullivan and Orr, 1982; Buck, 1982; and Pritsker, 1979). See Columns 4 and 5 of the MFPMM for these values from the scenario developed by this management group. If no changes are made for a given quantity or price/cost, the model assumes that the current period value (period 2, immediate past month, in this case) remains the same for period 3, or the next/projected period. Once all variables that are to be changed for a given scenario have been entered, the program can be run. On minicomputers, such as the TRS-II, IBM-PC, and

| Input | | | Future Period: ____ | |
|---|---|---|---|---|
| *CATEGORY NUMBER | CATEGORY NAME | ESTIMATE SEQUENCE ↓ ± | QUANTITY | PRICE |
| | | P = pessimistic<br>M = most likely<br>O = optimistic | | |
| | | P<br>M<br>O | | |
| | •<br>•<br>•<br>• | •<br>•<br>•<br>• | | |

| Output | | | Future Period: ____ | |
|---|---|---|---|---|
| *CATEGORY NUMBER | CATEGORY NAME | ESTIMATE SEQUENCE ↑ ± | QUANTITY | PRICE |
| | | P<br>M<br>O | | |
| | | P<br>M<br>O | | |
| | | •<br>•<br>• | •<br>•<br>• | •<br>•<br>• |

**Figure 5.10 Simulation Change Sheet**

Apple, the simulation routine may take up to 15 minutes (a good time for a coffee break). On small business computers, such as the HP3000, or larger systems the response time depends primarily on printer speed.

The analyst's skills in interpreting the MFPMM now play a big role in the effectiveness of this session. Results of the MFPMM will appear on the terminal (each manager might have his or her own), a hard copy can be generated, and with video out and the right equipment the results can be presented on a big screen TV or on a projection screen. The first and most obvious element to examine is Column 19 for total inputs. The management group can see how close they came to meeting their target of −\$0.00 change in profits from period 1 to period 3. Additionally, a histogram depicting the results of 100 simulation runs is generated and the managers can obtain a better feel for the characteristics of the probability distribution for the specific scenario they have developed. The

**Table 5.7a Example Simulation Scenario for LINPRIM Boat Company Example (VPI/VPC Version MFPMM)**

YOUR CURRENT VALUES FOR QUANTITY ARE AS FOLLOWS:

| NO. | CATEGORY NAME | QUANTITY PESS. | QUANTITY M.LIKELY | QUANTITY OPTM. |
|---|---|---|---|---|
| 1 | BOAT A | 55. | 65. | 70. |
| 2 | BOAT B | 35. | 45. | 55. |
| 3 | TOTAL OUTPUTS | 0 | 0 | 0 |
| 4 | LABOR MANAGEMENT | 304. | 304. | 304. |
| 5 | LABOR GLASS | 760. | 760. | 760. |
| 6 | LABOR ASSEMBLY | 1064. | 1064. | 1064. |
| 7 | TOTAL LABOR | 0. | 0. | 0. |
| 8 | FIBERGLASS | 3000. | 3000. | 3000. |
| 9 | WOOD | 1000. | 1000. | 1000. |
| 10 | TOTAL MATERIALS | 0. | 0. | 0. |
| 11 | ELECTRICITY | 8200. | 8200. | 8200. |
| 12 | NATURAL GAS | 70. | 70. | 70. |
| 13 | TOTAL ENERGY | 0. | 0. | 0. |
| 14 | TOTAL INPUTS | 0. | 0. | 0. |

YOUR CURRENT VALUES FOR PRICE ARE AS FOLLOWS:

| NO. | CATEGORY NAME | PRICE PESS. | PRICE M.LIKELY | PRICE OPTM. |
|---|---|---|---|---|
| 1 | BOAT A | 5500.00 | 6000.00 | 6500.00 |
| 2 | BOAT B | 12000.00 | 12000.00 | 12000.00 |
| 3 | TOTAL OUTPUTS | .00 | .00 | .00 |
| 4 | LABOR MANAGEMENT | 22.00 | 22.00 | 22.00 |
| 5 | LABOR GLASS | 7.00 | 7.00 | 7.00 |
| 6 | LABOR ASSEMBLY | 7.00 | 7.00 | 7.00 |
| 7 | TOTAL LABOR | .00 | .00 | .00 |
| 8 | FIBERGLASS | 75.00 | 70.00 | 55.00 |
| 9 | WOOD | 3.00 | 3.00 | 3.00 |
| 10 | TOTAL MATERIALS | .00 | .00 | .00 |
| 11 | ELECTRICITY | .10 | .10 | .10 |
| 12 | NATURAL GAS | 4.00 | 4.00 | 4.00 |
| 13 | TOTAL ENERGY | .00 | .00 | .00 |
| 14 | TOTAL INPUTS | .00 | .00 | .00 |

*(a)*

This part of the program performs a "what if" game on the model. It can give you all available options based on any desired value in Col. 17 for total inputs. In order to effectively use this program, you have to make estimates regarding quantity and price for the next period as we go along in this part. If you want to continue in this part of the program answer "Yes"; otherwise, "No" ? ?Yes. Do you want to compare periods 2 & 3? Yes/No: ?No. Do you want to compare periods 1 & 3? Yes/No: ?Yes. Enter desired value in Col. 17 for total inputs: ?0.

Now, you are required to indicate a three point estimate, namely: pessimistic, most likely, and optimistic values for quantity and price of each category you choose to vary for the next period. For variables, these estimates are not made. It is assumed that the present values of quantity and price are same for the next period, too.

histogram plots the column 19 values associated with each of the 100 simulated trials. Other graphics, such as this histogram, could be developed and immediately prepared in this planning session for review. (see Figure 5.9.)

Productivity, price recovery, and profitability index trend charts (performance trend charts) can be updated with forecasted scenario output and presented for review (see Figure 5.11). This evaluation of scenarios can go on as long as management desires. Typically, this part of the monthly performance/productivity improvement planning session would last approximately one hour.

The next step in this planning session is to begin to develop specific action plans relative to the most preferred scenario. For this step, the management group must agree on the desired scenario they wish to work toward and then thinking through specific actions that will need to be taken by specific individuals

**Table 5.7*b* Forecasted Scenario Output for LINPRIM Boat Example (VPI/VPC Version)**

MULTI-FACTOR PRODUCTIVITY MEASUREMENT
VPI/VPC VERSION

| | PERIOD 1 | | | PERIOD [illegible] | | |
|---|---|---|---|---|---|---|
| | (1) QUANTITY | (2) PRICE | (3) VALUE | (4) QUANTITY | (5) PRICE | [illegible] |
| BOAT A | 50. | 5000.00 | 250000.00 | [illegible] | [illegible] | [illegible] |
| BOAT B | 30. | 10000.00 | 300000.00 | 45. | [illegible] | [illegible] |
| TOTAL OUTPUTS | | | 550000.00 | | | [illegible] |
| LABOR MANAGEMENT | 320. | 20.00 | 6400.00 | [illegible] | [illegible] | [illegible] |
| LABOR CLASS | 300. | [illegible] | 6400.00 | [illegible] | [illegible] | [illegible] |
| LABOR ASSEMBLY | 1120. | 6.00 | 6720.00 | [illegible] | [illegible] | [illegible] |
| TOTAL LABOR | | | 19520.00 | | | [illegible] |
| FIBERGLASS | 2200. | 50.00 | 110000.00 | [illegible] | [illegible] | [illegible] |
| WOOD | 750. | 3.00 | 2250.00 | [illegible] | [illegible] | [illegible] |
| TOTAL MATERIALS | | | 112250.00 | | | [illegible] |
| ELECTRICITY | 8000. | .10 | 800.00 | [illegible] | [illegible] | [illegible] |
| NATURAL GAS | 90. | 4.00 | 360.00 | [illegible] | [illegible] | [illegible] |
| TOTAL ENERGY | | | 1160.00 | | | [illegible] |
| TOTAL INPUTS | | | 132930.00 | | | [illegible] |

or groups in order to cause the scenario to become a reality. Again, as has been mentioned, some changes that are projected to occur are controllable, others are not. Obviously, the action plans that are specifically developed will be proactive about those things that can be controlled and reactive to negative trends and their impacts. An example of an action plan assignment (responsibility and accountability) format for this case scenario is depicted in Figure 5.12.

In summary, it may be valuable to step back and examine this performance/productivity planning process in generic perspective. The productivity management process model presented in Chapter 2, Figure 2.1, will facilitate this. In this planning meeting just discussed, the management team has reviewed the output from their performance measurement decision support systems. As presented, the MFPMM played an integral role in this performance measurement process. The management group evaluated the data from the MFPMM and other performance measurement systems. They developed and evaluated projected scenarios of company performance utilizing the MFPMM simulation subroutine. They developed specific action plans necessary to cause the most desirable scenario to be achieved. The commitment to and quality of follow-through on these action plans by the various managers and functions involved will eventually determine the degree to which performance and productivity will be controlled and improved. Planning was necessary and was involved in order to

**Table 5.7c LINPRIM Boat Example, Columns 7–13 (MFPMM) (VPI/VPC Version)**

| | WEIGHTED CHANGE RATIOS | | | COST/REVENUE RATIOS | | PRODUCTIVITY RATIOS | |
|---|---|---|---|---|---|---|---|
| | (7) QUANTITY | (8) PRICE | (9) VALUE | (10) PERIOD 1 | (11) PERIOD 3 | (12) PERIOD 1 | (13) PERIOD 3 |
| BOAT A | 1.2333 | 1.2000 | 1.480 | | | | |
| BOAT B | 1.5000 | 1.2000 | 1.800 | | | | |
| TOTAL OUTPUTS | 1.3788 | 1.2000 | 1.655 | | | | |
| LABOR MANAGEMENT | 0.9500 | 1.1000 | 1.045 | 0.0116 | 0.0073 | 85.94 | 124.73 |
| LABOR GLASS | 0.9500 | 1.1250 | 1.069 | 0.0116 | 0.0075 | 85.94 | 124.73 |
| LABOR ASSEMBLY | 0.9500 | 1.1667 | 1.108 | 0.0122 | 0.0082 | 81.85 | 118.79 |
| TOTAL LABOR | 0.9500 | 1.1311 | 1.075 | 0.0355 | 0.0231 | 28.18 | 40.89 |
| FIBERGLASS | 1.3636 | 1.3333 | 1.818 | 0.2000 | 0.2198 | 5.00 | 5.06 |
| WOOD | 1.3333 | 1.0000 | 1.333 | 0.0041 | 0.0033 | 244.44 | 257.78 |
| TOTAL MATERIALS | 1.3630 | 1.3268 | 1.808 | 0.2041 | 0.2231 | 4.90 | 4.96 |
| ELECTRICITY | 1.0250 | 1.0000 | 1.025 | 0.0015 | 0.0009 | 687.50 | 924.80 |
| NATURAL GAS | 0.9000 | 1.0000 | 0.900 | 0.0007 | 0.0004 | 1375.00 | 2106.48 |
| TOTAL ENERGY | 0.9833 | 1.0000 | 0.983 | 0.0022 | 0.0013 | 458.33 | 642.66 |
| TOTAL INPUTS | 1.2990 | 1.3036 | 1.693 | 0.2418 | 0.2474 | 4.14 | 4.39 |

*(c)*

**Table 5.7d LINPRIM Boat Example, Columns 14–19 (MFPMM) (VPI/VPC Version)**

| | WEIGHTED PERFORMANCE INDEXES | | | DOLLAR EFFECTS ON PROFITS | | |
|---|---|---|---|---|---|---|
| | CHANGE IN | | | | | |
| | (14) PRODUCTIVITY | (15) PRICE RECVRY | (16) PROFITABILITY | (17) CHANGE IN PRODUCTIVITY | (18) CHANGE IN PRICE RECOVERY | (19) CHANGE IN PROFITABILITY |
| BOAT A | | | | | | |
| BOAT B | | | | | | |
| TOTAL OUTPUTS | | | | | | |
| LABOR MANAGEMENT | 1.451 | 1.091 | 1.583 | 2744.24 | 1156.85 | 3901.09 |
| LABOR GLASS | 1.451 | 1.067 | 1.548 | 2744.24 | 1004.85 | [illegible] |
| LABOR ASSEMBLY | 1.451 | 1.029 | 1.493 | 2881.46 | 789.09 | 3670.55 |
| TOTAL LABOR | 1.451 | 1.061 | 1.540 | 8369.94 | 2950.79 | [illegible] |
| FIBERGLASS | 1.011 | 0.900 | 0.910 | 1666.67 | [illegible] | [illegible] |
| WOOD | 1.034 | 1.200 | 1.241 | 102.27 | 620.45 | [illegible] |
| TOTAL MATERIALS | 1.012 | 0.904 | [illegible] | [illegible] | [illegible] | [illegible] |
| ELECTRICITY | [illegible] | 1.200 | 1.414 | [illegible] | [illegible] | [illegible] |
| NATURAL GAS | [illegible] | 1.200 | [illegible] | [illegible] | [illegible] | [illegible] |
| TOTAL ENERGY | [illegible] | 1.200 | [illegible] | [illegible] | [illegible] | [illegible] |
| TOTAL INPUTS | 1.061 | 0.921 | 0.977 | [illegible] | [illegible] | [illegible] |

*(d)*

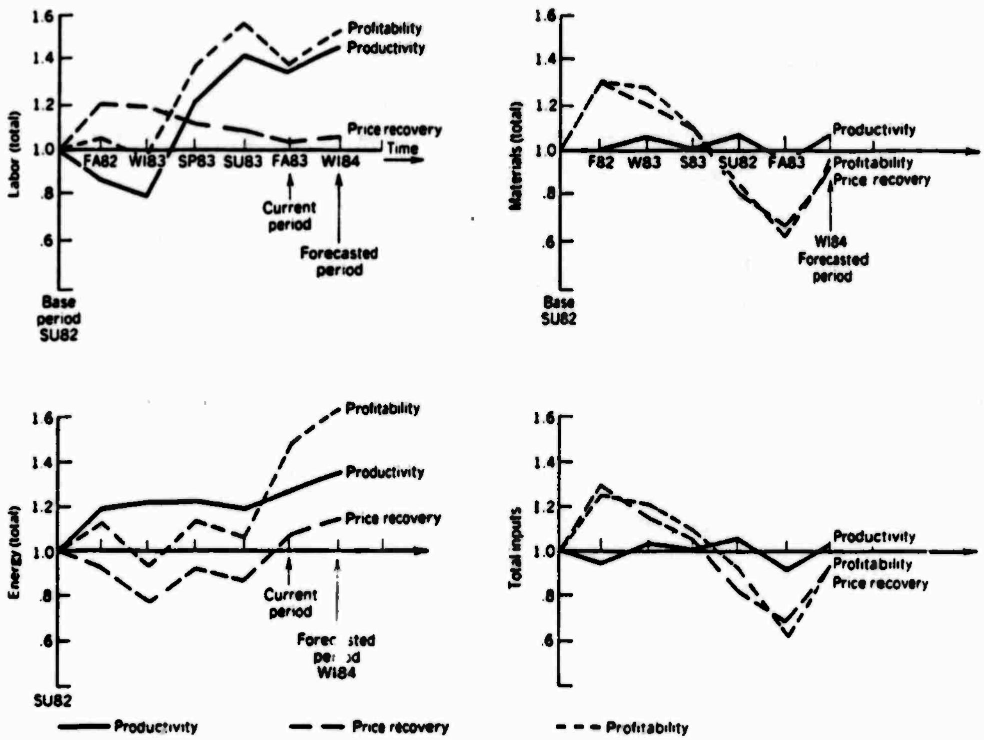



**Figure 5.11 Performance Trend Charts (Columns 14–16 plotted over time)**
**—— Productivity —— Price Recovery -------- Profitability**

develop action plans that would have a high probability of controlling and improving performance and productivity. So from Figure 5.13, which was first presented in Chapter 2, it can now perhaps be more easily observed and understood how the productivity management process actually can and should take place in an organization.

| | IDEA FOR: PRODUCTIVITY IMPROVEMENT | IDEA FOR: PERFORMANCE IMPROVEMENT | PERIOD 2 VALUE | PERIOD "3" TARGETED CHANGE | SIMULATED POTENTIAL IMPACT | RESPONSIBILITY & ACCOUNTABILITY |
|---|---|---|---|---|---|---|
| THE MAJOR, PLANNED FOR PRODUCTIVITY IMPROVEMENT STRATEGIES | | Sales of:<br>Boat *A*<br>Boat *B*<br>↑ Price of:<br>Boat *A*<br>Boat *B* | 70<br>35<br>5500<br>12000 | 61<br>45<br>6000<br>12000 | • ↑ Rev. to $906,000 from $805,000<br>• | Marketing, Sales, Production |
| | Hold labor constant<br>• wages<br>• hours | | | | • $8369 Prod.<br>• $2808 P.R.<br>• $11,178 Total | Human Resources, Production, All management, Industrial Engineering |
| | | Reduce Fiberglass Cost (unit) | 85 | 67 | • $60,000 reduction in price recovery loss from period 2 to 3 | Purchasing, Industrial Engineering |
| SECONDARY STRATEGIES MANAGEMENT BASICS | Materials Management | | 1.93)<br>7%<br>prod.<br>loss | (1.01)<br>1%<br>prod.<br>gain | • $1768 | Manufacturing, Industrial Engineering |
| | Energy Management | | Col. 12<br>1.29 | Col. 12<br>1.36<br>36% gain in prod. | • $419 | Industrial Engineering |

**Figure 5.12 MFPMM Decision Support System—Monthly Productivity Improvement Planning Session Action Plan Assignment**

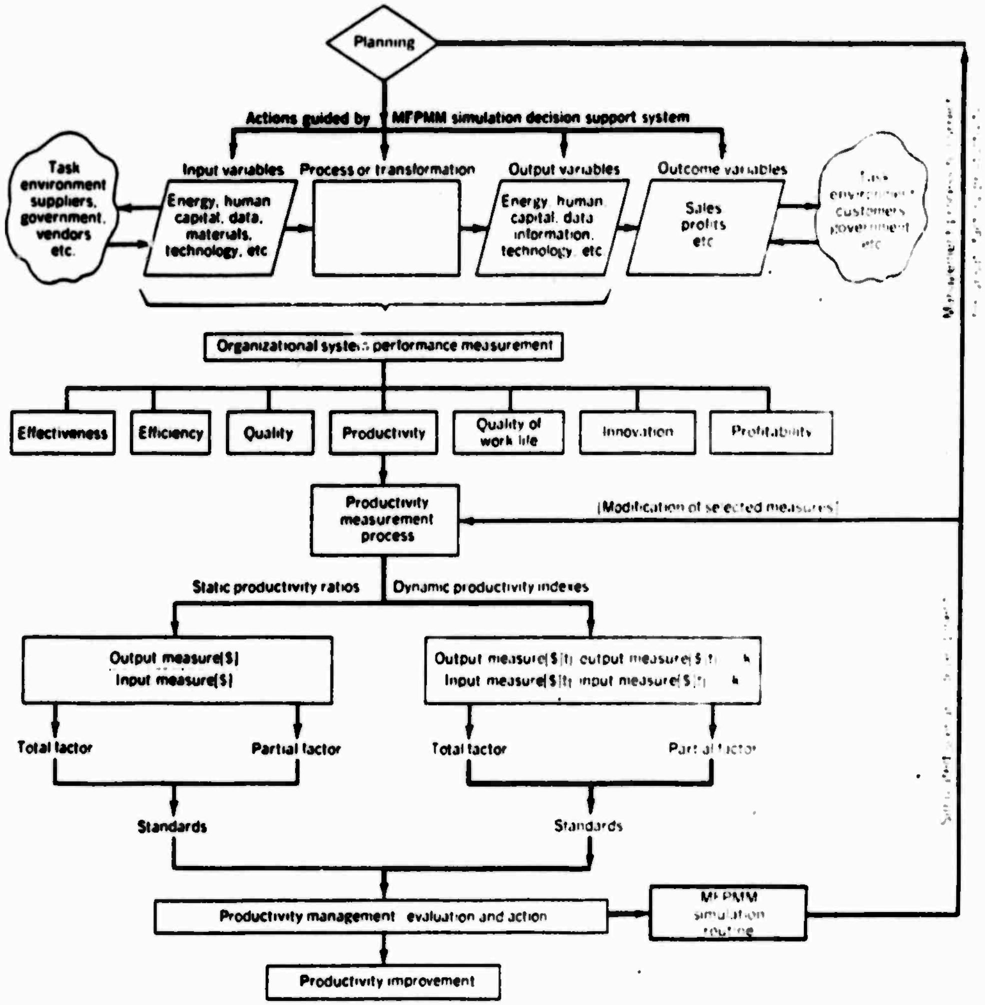



**Figure 5.13 Productivity Management Process**

## *MFPMM Software Support*

The MFPMM is a highly interactive, online system possessing several appealing software features that make it a valuable decision support system. Complete documentation in the form of a user's guide that describes the model and its features is available to assist the new user with implementation of the MFPMM. The software features will be briefly described here in essentially the same sequence they would appear during execution.

### *Data Input*

Quantity and price for each output and input of the entity being analyzed are required to run the model. This information can be entered into the model by reading it from an existing data file or inputting it interactively. If the data are input interactively, the user has the option of running the model only once with the data or sending the data to a file to be saved for future use. Either way the data are entered, only a short response is required from the user. (Sometimes a "Y" for yes or an "N" for no is all that is necessary.)

After the data are entered, the model displays the data as they exist to the user for verification. The data are segmented into small sections for ease of viewing on a CRT. As each section is displayed, the user has the opportunity to change any of the data for that particular execution. If the data that were changed existed in a file, the file will not be changed.

### *Base-to-Current-Period Analysis*

Once quantity and price data have been entered and verified, three tableaus are displayed providing the user with a dynamic productivity report. After the tableaus are displayed, the user has the opportunity to receive a hard copy of the tableaus by simply answering "Y" for yes. The user will then be given instructions pertaining to the sensitivity analysis stage of the model and asked if he or she wants to continue. Answering "Y" will enable the user to proceed; answering "N" will terminate the session.

### *Sensitivity Analysis*

Probably the most appealing feature of the VPI/VPC model is the simulation routine, which allows a sensitivity analysis of projected data. This feature essentially allows the user to play a "what-if" game with the model. The user has the opportunity to compare a projected period to the base period or the current period, but first he or she must enter a desired future value for "total inputs' effect on change in profitability" (last row in Column 19). For example, if the user were comparing a projected period to the current period and he or she did not want his or her level of profitability to change, he or she would enter a desired value of "0."

In order to perform the sensitivity analysis of projected data, pessimistic, most likely, and optimistic estimates must be entered for each category the user wishes to vary in the projected period. Any combination of output and input quantities and prices can be projected.

After all quantity and price projections have been made, a histogram plot and probability statement are displayed. The histogram depicts the results of Monte Carlo simulation, which has generated 100 random outcomes. The 100 data points on the histogram represent the 100 simulated values for total inputs' effect on change in profitability based on projections. The probability statement tells the user how many of the 100 simulated values were greater than or equal to the desired value. The histogram and probability statement give the user a very good indication as to whether or not the projected scenario will result in the desired change in profitability without even looking at the tableaus.

After the histogram plot and probability statement are displayed, the user has the opportunity to create another scenario (make more projections or change some of the previous projections). For each scenario created, a histogram plot and probability statement can be generated. Again, the user has the opportunity to get a hard copy if desired.

When the user has completed this part of the session, the three tableaus will be displayed again with the results reflecting projected period values. During both the base-to-current period analysis and the projected-period analysis, the user has the option of seeing all three tableaus or just the total inputs line of the third tableau (Columns 14–19). Throughout execution of the model, the user is given opportunities to have hard copies printed of what is on the CRT if a printer is available.

The model as it exists is extremely "user-friendly," but the model is continually being developed and refined. Also, added graphics capabilities are being investigated as a means of improving the clarity with which results can be displayed and understood. Industry pilot studies with the model are underway, and it is anticipated that the experience gained through participation in these pilot studies will contribute to further MFPMM enhancements. More information regarding software support can be obtained by contacting the author.

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# APPENDIX A.4

## Detailed Description of LTV's Integrated Approach

## LTV's Integrated Approach

LTV Aerospace and Defense Company's Vought Aero Products Division (VAPD) has developed a comprehensive productivity improvement program that operates at different levels of business activity, from total corporation down through departmental levels. The program assimilates productivity improvement themes into the routine operations of the company by focusing attention on the following:

1. Strategic Plan: establish competitive productivity targets
2. Development Plan: select projects with employee participation
3. Budgets: synchronize budgetary controls with productivity targets
4. Operations: use measurements to monitor performance
5. Profits: apply Department of Defense (DOD) incentives to generate savings and profits

## Competitive Targets

Companies can establish competitive targets for productivity improvement with the aid of a mathematical relationship that exists between profitability, productivity and price-recovery:

$$\boxed{\frac{\text{COST}}{\text{SALES}}} = \boxed{\frac{\text{RESOURCE QUANTITY}}{\text{PRODUCT QUANTITY}}} \times \boxed{\frac{\text{RESOURCE PRICE}}{\text{PRODUCT PRICE}}} \quad \ldots(1)$$

$$\boxed{\text{PROFITABILITY}} = \boxed{\text{PRODUCTIVITY}} \times \boxed{\text{PRICE-RECOVERY}}$$

Here profitability is the ratio of "cost" to "sales". Productivity is the "input:output" relation of resources consumed and products or services produced. Price-recovery deals with relative inflation, or the extent to which increases in the cost of resources are recovered through product price changes. The mathematical relationship remains just as true for a whole industry as for individual corporations.

Since forecasts of industry sales, profits and inflation are commercially available, it is possible to calculate an industry's anticipated productivity improvement. Companies can, therefore, compare their own potential for improvement with the industry and select a competitive productivity target which will produce, over time, a strategic advantage in pricing (Figure 1).

## Productivity Projects

Productivity is not a new imperative. It has been relevant since the start of the industrial revolution. In the early years of industrialization, production methods were labor intensive. Therefore, the effort to improve operations was focussed on "production efficiency". This started a tradition which narrowly associated productivity with production labor. That single-minded attention to production is undergoing a change. Improvements in manufacturing technology have modified the cost structure of products. The cost drivers have shifted from production to support and overhead areas (Figure 2). In the context of total company modernization, therefore, a local focus on manufacturing is insufficient. Manufacturing modernization, by itself, cannot fulfill the goal of competitive improvements in productivity. Productivity goals must, therefore, be broadened. To appreciate the diverse applications of new projects for productivity improvement, consider the list in Table 1. The cited projects are a small selection from the wide range of modernization initiatives being taken at Vought Aero Products Division. They nevertheless demonstrate that it is feasible to simultaneously address all facets of company costs.

Total modernization of a company is a substantial task and it is helpful to accomplish it in a cooperative effort by all employees. VAPD utilizes the Nominal Group Tecnique [1,2] to conduct employee participation meetings and generate ideas for productivity improvement. Employees vote on their ideas

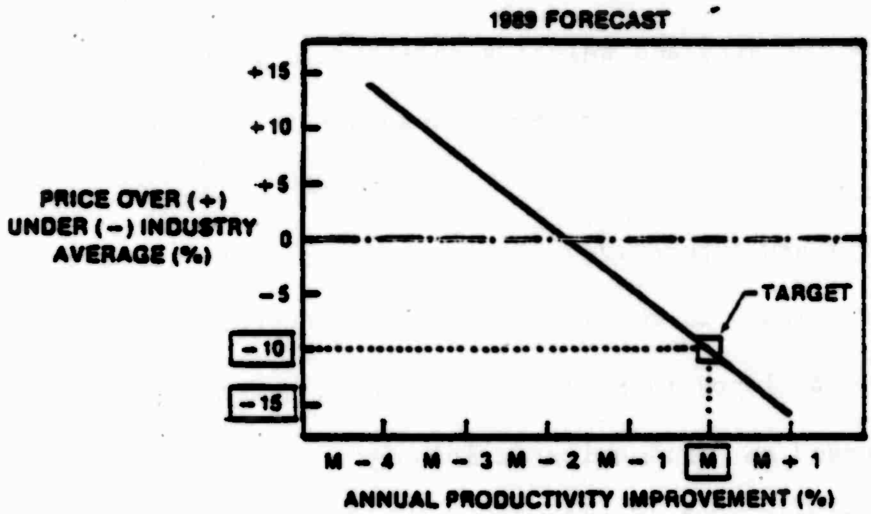



FIGURE 1 COMPETITIVE PRICING BENEFITS

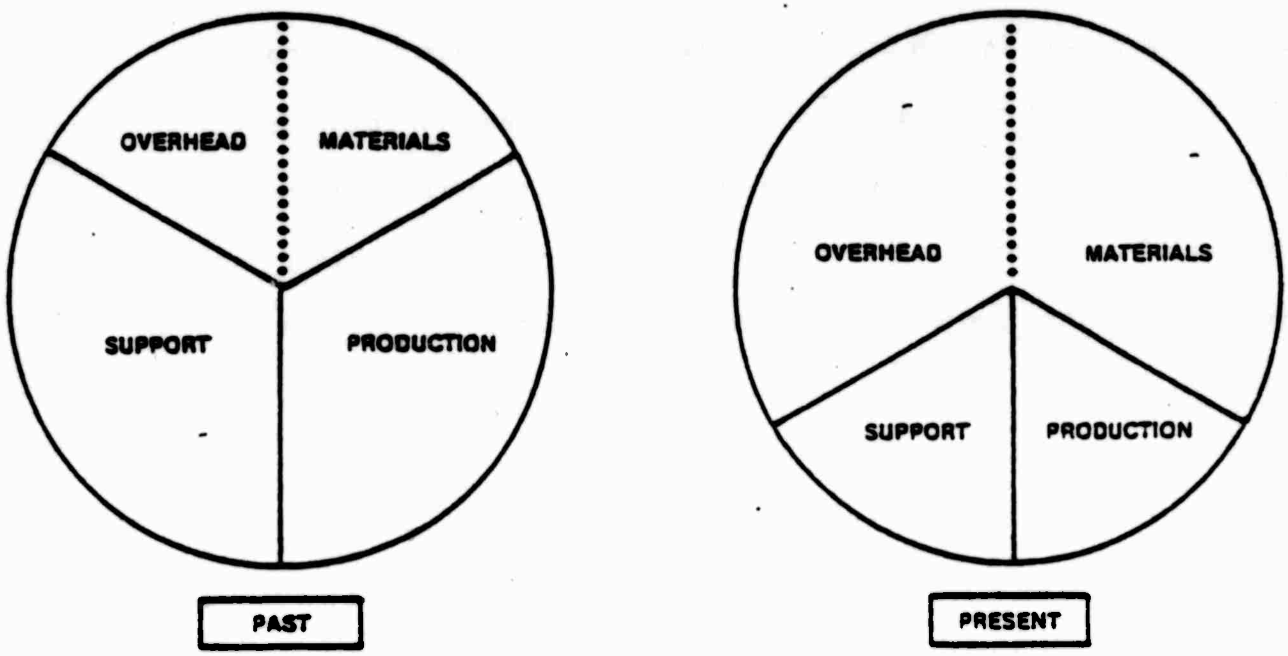



FIGURE 2 CHANGE IN COST DRIVERS

TABLE 1 PRODUCTIVITY PROJECTS

| PROGRAM | FOCUS |
|---|---|
| • FLEXIBLE MANUFACTURING | PRODUCTION |
| • COMPUTER-AIDED DESIGN<br>• COMPUTER-AIDED MANUFACTURING | ENGINEERING SUPPORT |
| • INVENTORY REDUCTION/JUST-IN-TIME | OVERHEAD |
| • AUTOMATED PROCUREMENT | MATERIALS |
| • OFFICE OF THE FUTURE | WHITE COLLAR |
| • EMPLOYEE BADGE BASED AUTOMATION (ENTRY, ATTENDANCE, PAYROLL) | SECURITY AND FINANCE |
| • ENERGY MANAGEMENT SYSTEMS | ENERGY |
| • ARTIFICIAL INTELLIGENCE BASED BIDS AND PROPOSALS | SALES |
| • AUTOMATED WAREHOUSING SYSTEMS | WAREHOUSING |
| • EMPLOYEE MOTIVATION AND GAINSHARING | GENERAL |

to create a ranked list. Higher ranked ideas are packaged into projects and cost analyzed for review by departmental management (Table 2). By this process, each department develops a long-range productivity improvement program for implementation in its area.

## Budgets and Controls

Competitive productivity improvement is a demanding objective. For a company incurring $1 billion in costs of goods sold, a 5% productivity improvement target implies annual cost reduction of about $50 million. Such goals require budgetary discipline. If an expansive budget is approved at the start of the year, it cannot yield cost efficiencies by year-end. The environment for cost improvement must be built into the budget, ahead of time.

Equation (1) suggests that productivity improvement targets and operating costs, or budgets, are mathematically related. Sales, costs and profits are all influenced by productivity. However, the scope of that influence is masked by inflation. If the effects of inflation are removed, by comparing sales and costs in "constant dollars", changes in productivity become apparent (Figure 3). VAPD uses these relationships to monitor cost and productivity trends at the company level. As shown in Figure 4, costs or budgets are expressed as a percentage of "output". Output is defined as "sales plus change in inventory". Management of this cost index is considered vital to the control of the total company budget.

Department level budgets can be derived from the total company budget by following two principles. First, the principle of limited resource states that total resources allocated to the departments must equal those allocated to the company. Within that premise, productivity targets do not have to be uniform in all departments. However, below nominal assignment of improvement targets to certain departments have to be compensated by above nominal

TABLE 2 PROJECT SELECTION AND ANALYSIS

## HUMAN RESOURCES

### EXAMPLE OF EMPLOYEE PARTICIPATION (NGT) RESULTS FOR ONE PROJECT

| RANKING | | PROJECT | VOTES | SCORE |
|---|---|---|---|---|
| [illegible] | [illegible] | | | |
| 11 | 2 | Employee Badge Based Automation:<br>• Closed Circuit TV Check at Entry and Exit<br>• Automated Attendance – Eliminate Time Cards<br>• Automated Vehicle Parking Assignment<br>• Automated Guard Assignment Schedules | 7 | 31 |
| Assigned to IMOD | | | | |

### COST ANALYSIS FOR PROJECT: EMPLOYEE BADGE BASED AUTOMATION

| PROJECT | POTENTIAL IMPROVEMENT | | | | IMPLEMENTATION COSTS $M | | FOCUS |
|---|---|---|---|---|---|---|---|
| | [illegible] | | [illegible] | | | | |
| | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| • Employee Badge Based Automation | 96<br>18<br>4000<br>– | 38<br>7<br>1400<br>– | 15.0<br>6.0<br>0.8<br>$ 2.5M/YR | 5.7<br>0.7<br>11.2<br>21.0<br>------<br>$ 4.825M | 4.2 | 2.0 | • Security<br>• Mail Room<br>• General<br>• Interest |

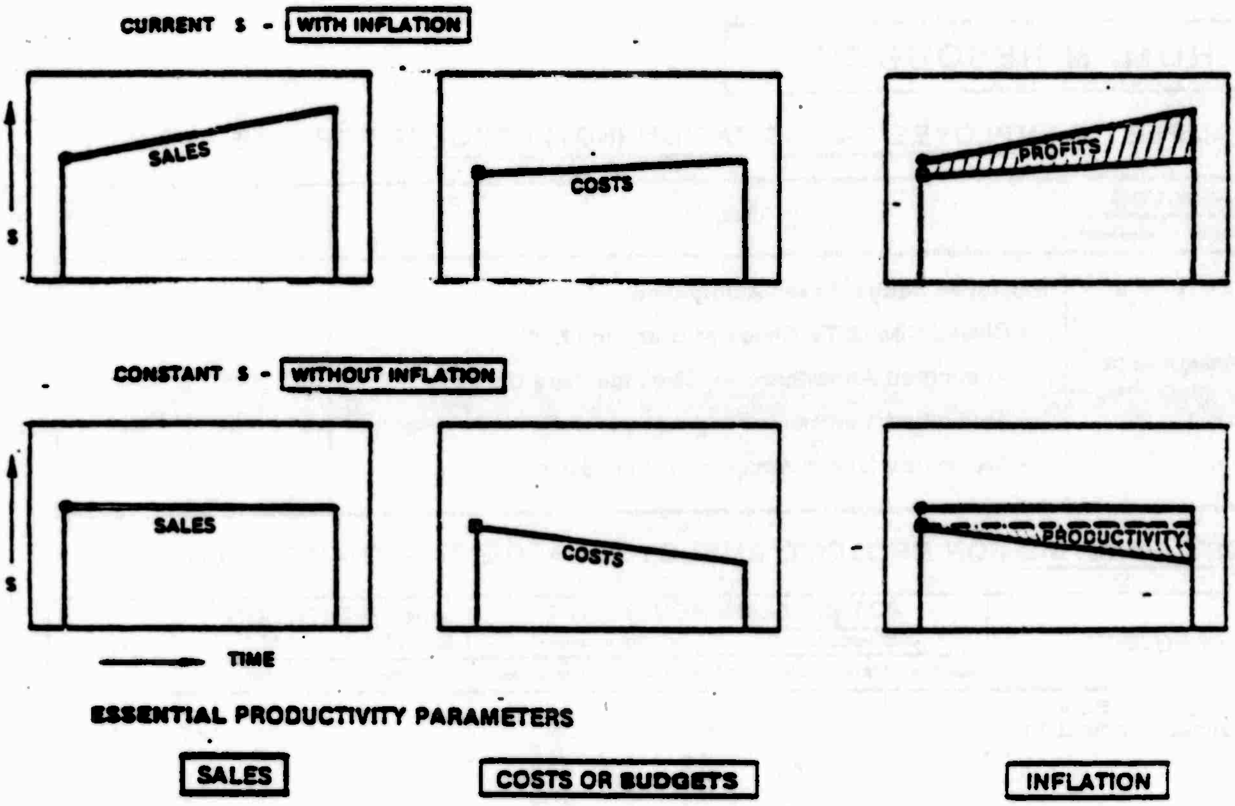



FIGURE 3 MODEL OF PRODUCTIVITY

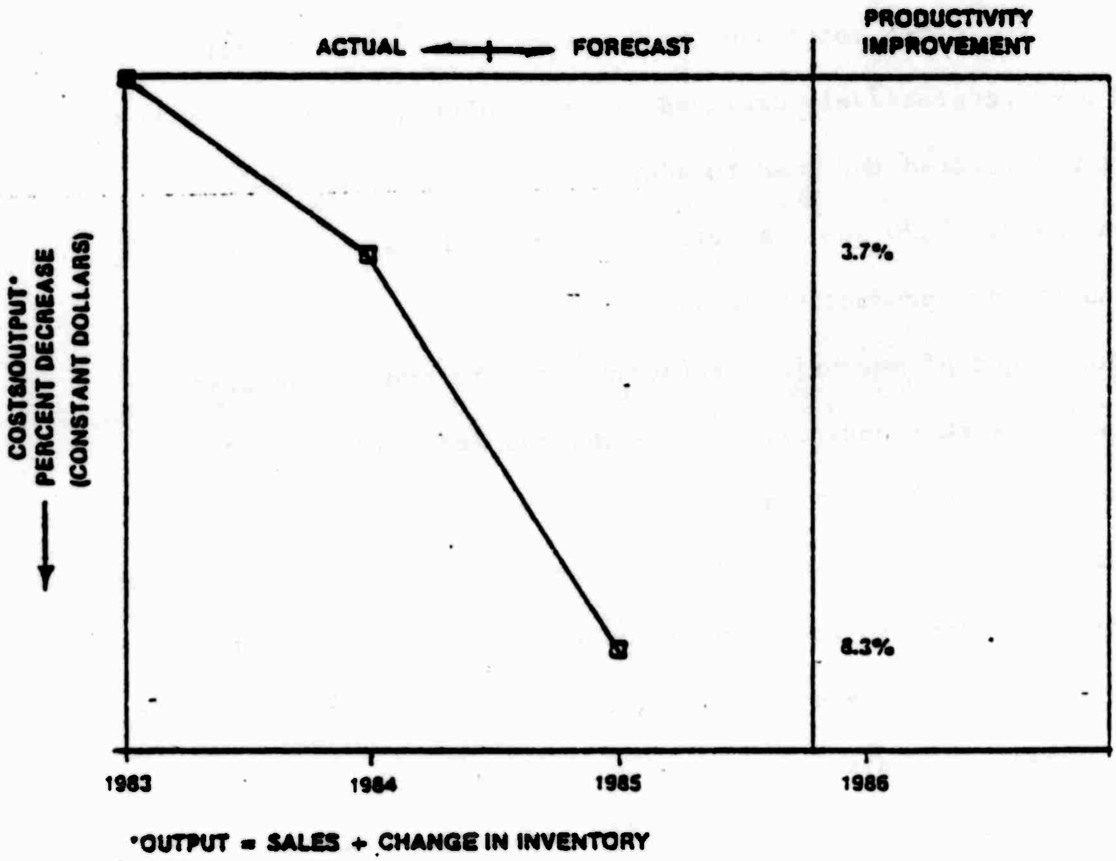



FIGURE 4 TREND OF DECLINING COSTS

assignment to others. Second is the principle of shared targets which states that the responsibility for improving productivity for a resource can be shared by two or more departments. For example, capital and energy resources are commonly shared. By making a fair, pre-negotiated allocation of the actual performance, favorable or otherwise, amongst sharing departments, team play can be encouraged.

<u>Performance Measurement</u>

Companies have used performance measurements in the production area for many years. However, production costs and their proportional ratio to total company costs have progressively declined. The resulting modification of the cost structure has created the need to address both production and non-production costs. VAPD has, therefore, expanded the application of measurements to its non-production areas.

The traditional method of measuring performance in the production area involves the use of work standards. Such standards are developed by a cost-intensive, analytical, multi-step method shown in Figure 5 A. While effective in the production area, this technique is costly, specialized, and cannot be universally applied to overhead and support functions. Therefore, VAPD uses other simpler and less cost-intensive methods for application in non-production areas. Techniques such as "input:output" or "activity:indicator" ratios [3], as shown in Figure 5 B are utilized to provide reliable measurement at a lower cost.

Figures 6 and 7 illustrate the performance charts used at the unit level and the department level. The charts feature sections denoted as "PERFORMANCE" and "RATING". The PERFORMANCE shown pertains to individual measurement. Since measurements are often diverse and cannot be mathematically added, the RATING category is used to convert all performances

**A. Production Areas**

WORK STANDARDS

TRACK PERFORMANCE
↑
WORK STANDARDS
↑
ESTIMATE VALUES
↑
IDENTIFY ELEMENTS
↑
STANDARD METHOD
↑
ANALYZE PRACTICE

**B. Non-Production Areas**

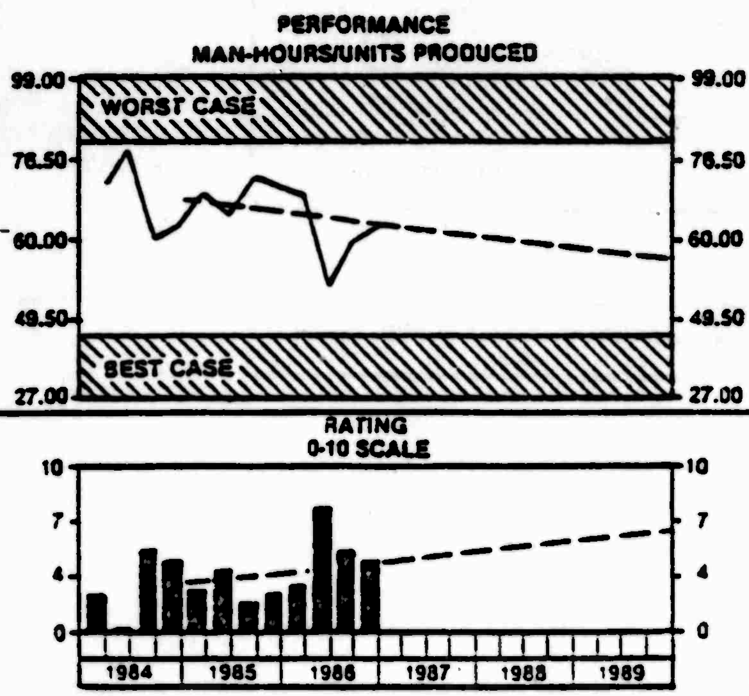
INPUT: OUTPUT

$\frac{\text{MAN-HOURS}}{\text{LOTS INSPECTED}}$

ACTIVITY: INDICATOR

$\frac{\text{NUMBER OF CUSTODIANS}}{\text{SQUARE FEET CLEANED}}$

FIGURE 5 MEASUREMENT TECHNIQUES




| | TARGET | ACTUAL |
|---|---|---|
| PRESENT QUARTER: | 63.052 | 63.000 |
| YEAR TO DATE: | 63.999 | 60.500 |

LEGEND
ACTUALS ——— TARGET — — —

| CASE | PERFORMANCE | RATING |
|---|---|---|
| BEST:* | 40.00 | 10.00 |
| WORST:* | 80.00 | 0.00 |
| PRESENT QUARTER: | 63.00 | 4.33 |
| YEAR TO DATE: | 60.50 | 5.39 |

* - JUDGEMENT CALLS

LEGEND
RATING ▓ TARGET — — —

FIGURE 6 UNIT LEVEL PERFORMANCE

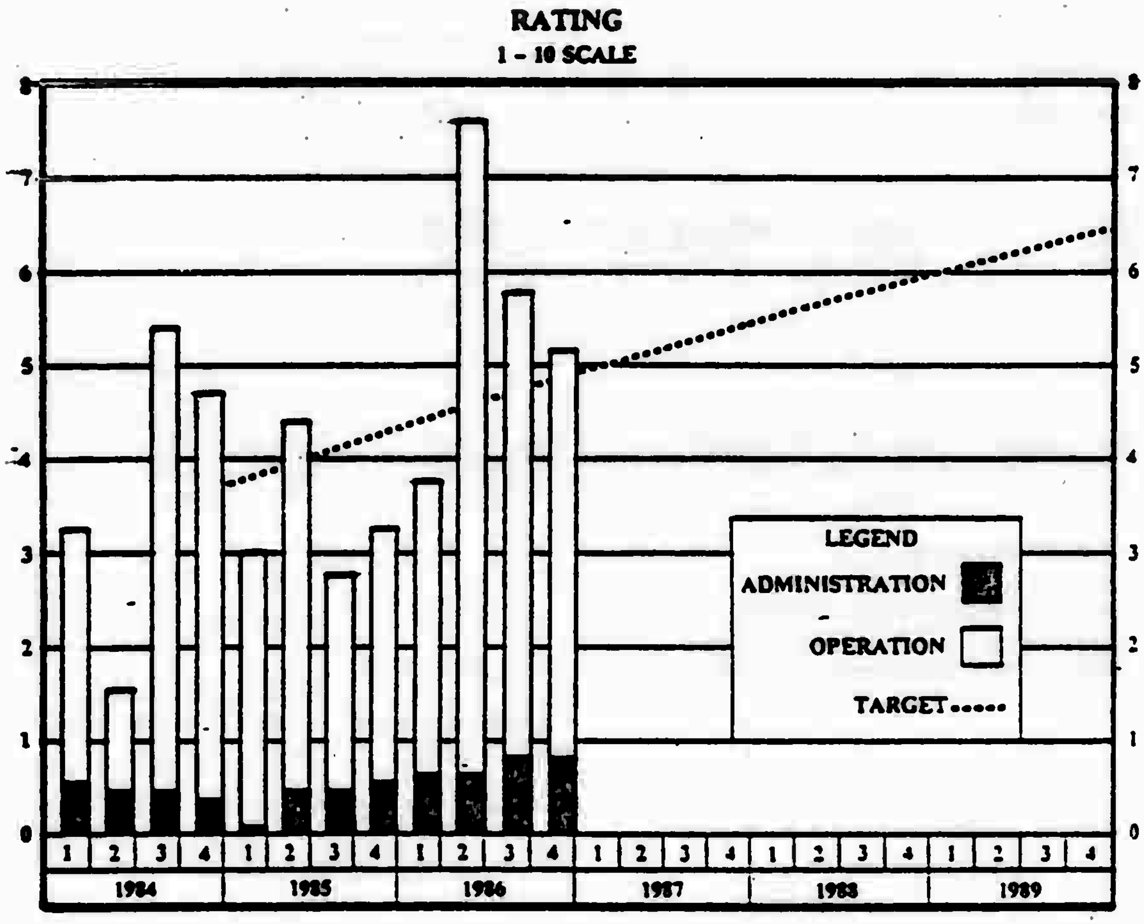



FIGURE 7 DEPARTMENT LEVEL PERFORMANCE

to a common scale of 0 ("worst case") to 10 ("best case"). Such a conversion allows comparison between diverse measurements, as well as calculation of a department's total performance. In this manner, measurements are used to monitor performance improvement and provide cost trends for future bids and proposals.

**Savings**

Two problems have been cited most frequently as inhibiting productivity improvement and modernization in defense contracts:

- Program uncertainties
- A cost-oriented profit policy

In the first instance, risks are introduced which hinder investment amortization and inhibit long-term planning. Due to the second problem, a contractor may actually see profits reduced as a result of efforts to improve productivity and reduce costs. DOD has introduced an Industrial Modernization Incentive Program (IMIP) as a tool to overcome these impediments[4]. The central idea in IMIP is to negotiate a business arrangement with benefits to both parties:

- Contractor - investment protection
  - shared savings
- Customer - reduced acquisition costs

Investment protection to the contractor overcomes risk associated with program instability. Shared savings on current and future programs increase the contractor's rate of returns and profits.

The IMIP program is especially attractive because its concept of shared savings can be applied to both manufacturing and non-manufacturing modernization. Since VAPD has a broad based program for productivity improvement initiatives in all departments, it has developed a uniform approach to IMIP which is based on the assumption that the contractor's shared savings would come from improvements in performance. Improvements are measured by comparing a pre-determined "baseline" performance with "actual" performances in the future (Figure 8). Readily available measurements are used to monitor the performance of modernization projects (Table 3). Shared savings for any given year are calculated in three steps as shown in Table 4. Step 1 measures "improvement", step 2 calculates "savings" and step 3 "allocates" savings to multiple programs. It should be noted that the IMIP program allows DOD agencies to mutually agree and designate a lead buying office for each company where IMIP is to be pursued. That buying office becomes the IMIP focal point for the contractor to accommodate modernization projects that cut across multiple programs.

The productivity improvement program described above serves the special needs of VAPD. While some of its features may have wider application, it is not a magic formula for success. More important than the structure of any program is the degree to which the usage of productivity tools becomes natural to a company's daily operation. A program, at its best, becomes so pervasive as to be anonymous.

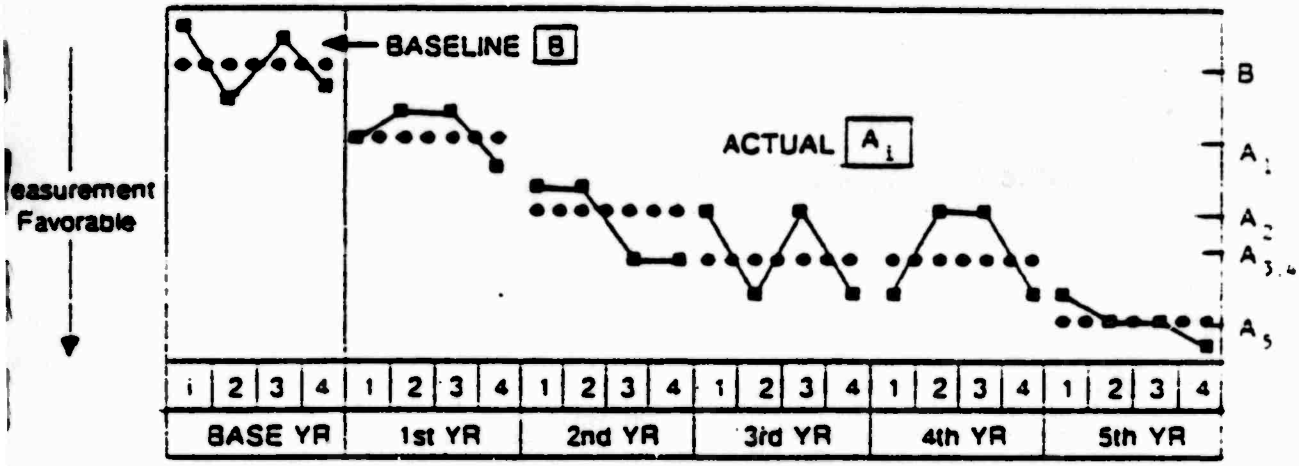



FIGURE 8 PERFORMANCE MEASUREMENT

TABLE 3 EXAMPLES OF MEASUREMENTS

| PROJECT | MEASUREMENT |
|---|---|
| OFFICE OF THE FUTURE | $ TECHNICAL PUBLICATIONS & REPRODUCTION / $ VAPD SALARIED LABOR COSTS |
| INVENTORY REDUCTION | $ AVERAGE WIP INVENTORY / $ ANNUAL SALES + CHANGE IN WIP |
| FLEXIBLE MANUFACTURING | $ COST OF SALES (AFFECTED PARTS) / $ AS-IS STANDARD HOURS |

TABLE 4 CALCULATION OF SHARED SAVINGS

Step 1 - Improvement:

| BASELINE PERFORMANCE | PERFORMANCE IN YEAR (i) | IMPROVEMENT (%) |
|---|---|---|
| B | Ai | (B - Ai) % |

Step 2 - Savings:

| INCREMENTAL SAVINGS PER PERCENT IMPROVEMENT ($/%) | TOTAL SAVINGS ($) | CONTRACTOR'S SHARE (%) | PSR ($) |
|---|---|---|---|
| Ii | Si = Ii (B-Ai) | C% | P = C · Si |

Step 3 - Allocation:

| Program | L | M | N | Total |
|---|---|---|---|---|
| Sales ± Change in WIP (%) | 20 | 50 | 30 | 100 |
| Allocated PSR ($) | 0.2P | 0.5P | 0.3P | P |

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2. Sink, D. S. "Productivity Action Teams: An Alternative Involvement Strategy to Quality Circles," Annual Industrial Engineering Conference Proceedings. Atlanta, Georgia: Institute of Industrial Engineers, 1981.

3. Lehrer, Robert N. White Collar Productivity, Chapter 9. New York: McGraw Hill Book Company, 1983.

4. Headquarters Naval Material Command. "Industrial Modernization Incentives Program, Circulation Comment Package". Washington, D. C., 1984.

## COST-BENEFIT ANALYSIS/COST-BENEFIT TRACKING AT VOUGHT AERO PRODUCTS

One of the functional components of the VAPD productivity improvement program is the cost-benefit analysis/cost-benefit tracking model. This model is linked to the remaining program models to create an integrated approach to productivity improvement. The model's generic approach is fully adaptable to multi-program manufacturing environments as well as to opportunities for non-production oriented improvements.

### COST DRIVER ANALYSIS

Traditionally, defense contractors have considered manufacturing as their primary cost driver. Developments in technology have produced a significant change in the cost structure of major contractors as evolving technology is implemented on the factory floor. The results of these efforts are best understood by examining Figure 1. In recent years, production technology applications and reduced production quantity requirements have worked together to dramatically shift cost drivers away from manufacturing toward the indirect functions of materials and overhead. These "indirect functions" have become the predominant cost drivers for defense contractors today.

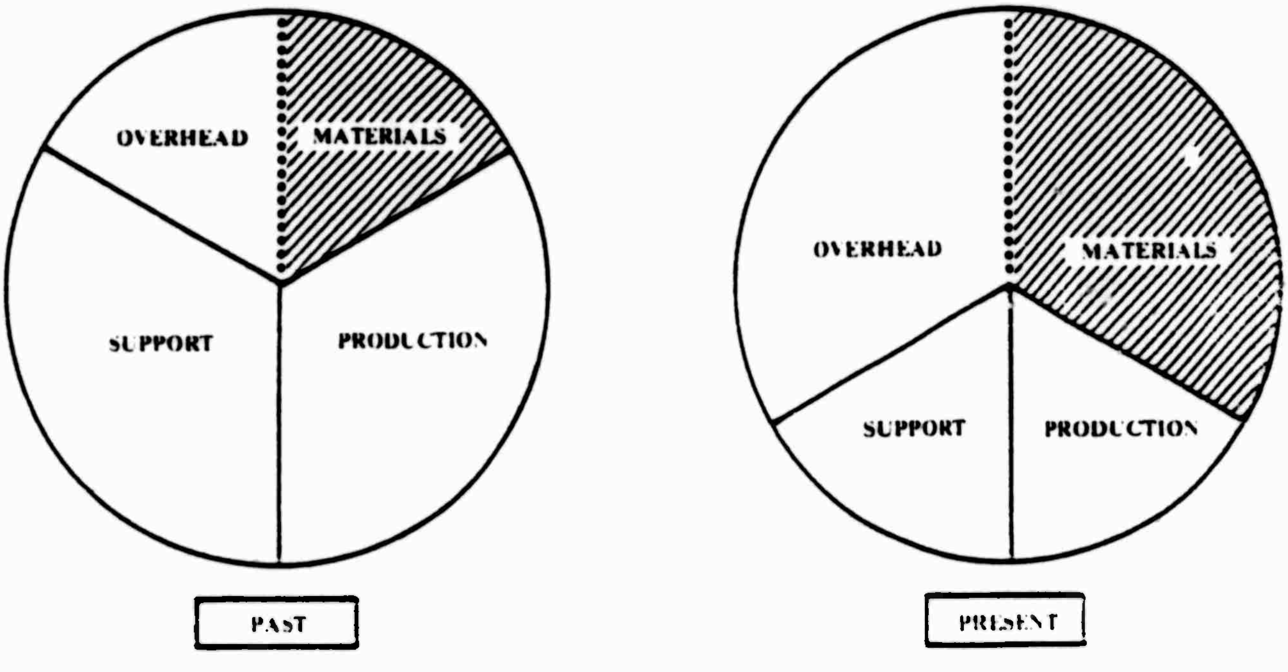



*Figure 1 Cost Driver Shift*

The cost driver shift demonstrates that contractor survival in today's competitive environment requires productivity improvement and cost savings in all functions, not just those associated with production. Hence, the scope of modernization efforts must the expanded to encompass the total factory.

IMIP offers an especially attractive means to approach total factory modernization because of its adaptability to both manufacturing and non-manufacturing functions. IMIP creates opportunities to address the shift in cost drivers by allowing contractors to tailor their participation to reflect their changing environment. In this respect, IMIP is a welcomed opportunity to those contractors who operate in a multi-program environment. With flexibility built into the program, defense contractors can develop approaches to modernization that maximize the productivity gain from project expenditures as well as reduce government procurement costs.

Maximizing productivity gains begins with contractor matching of modernization projects to cost drivers. This approach follows the concept of "going after the moose, not the mice" by addressing those cost drivers or components that offer the best potential for productivity gains. Once the cost driver analysis is completed, a formal plan for addressing these opportunities can be formulated in terms of specific modernization projects. A typical cost driver based modernization plan is shown in Figure 2 for the materials functions.

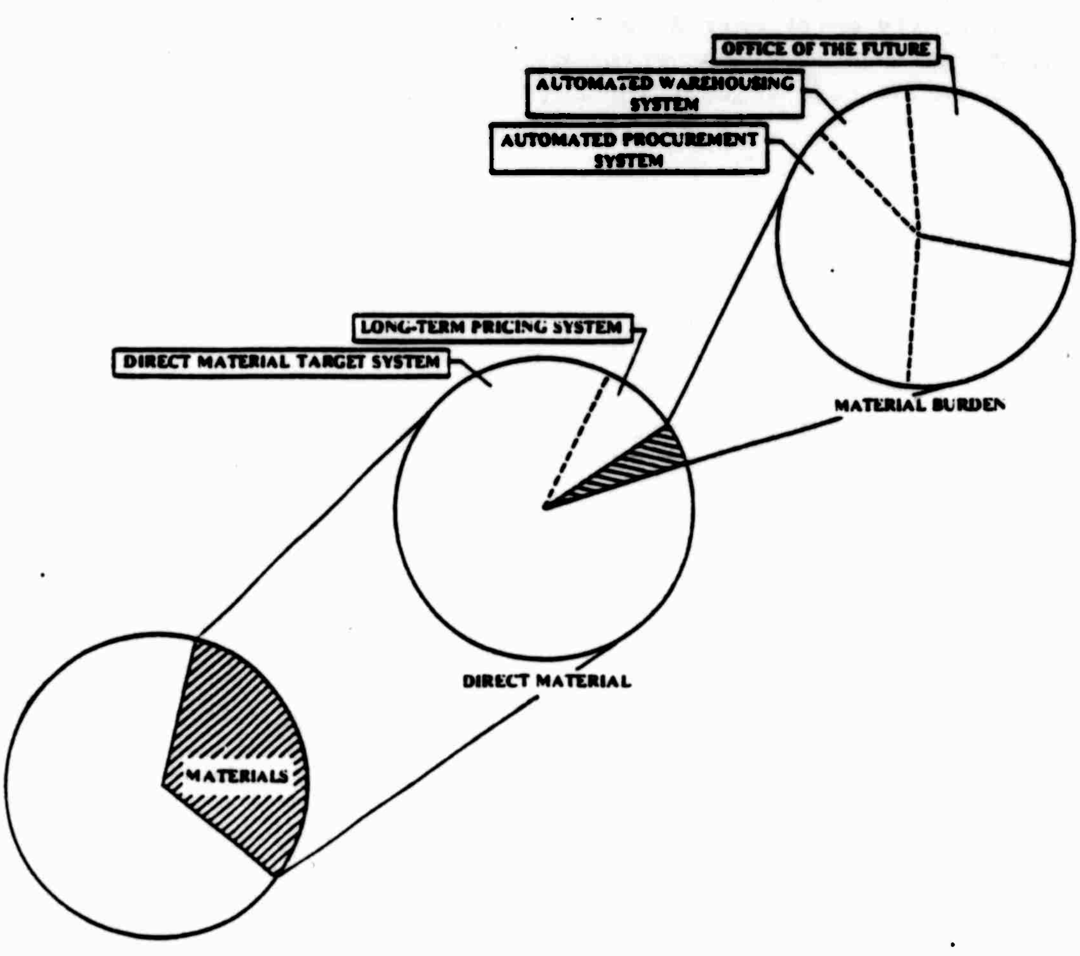



*Figure 2 Cost-Driver-Based Modernization Plan for Materials Function*

Success in using this approach depends upon a sufficiently detailed cost driver analysis and the identification of each project's major impact area. The structured examination of project impact will often result in project application to synergic multiple cost areas and therefore expand the potential for productivity gain.

## IMIP Master Contract

Most contractors who operate in a multi-program environment will find it beneficial to use an IMIP approach that is conducive to that environment. IMIP allows the utilization of a Master Contract Methodology that facilitates a more practical application to operating structures and business bases. The approach is best structured in terms of the example shown in Figure 3.

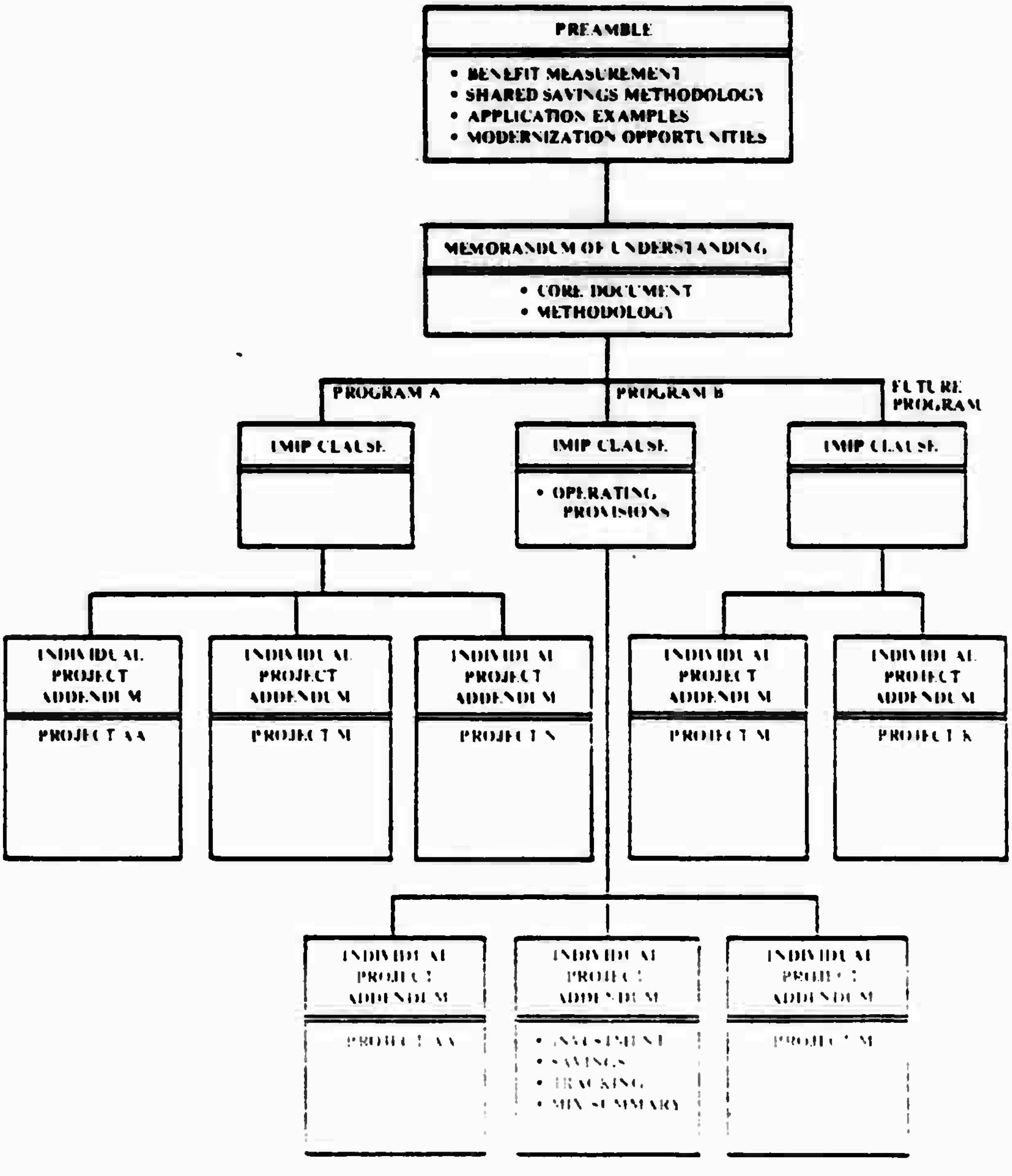



Figure [illegible]

## Preamble and Memorandum of Understanding

The baseline Master Control includes the Preamble and Memorandum of Understanding (MOU) that serve as the formal contractual building blocks for any IMIP effort. The Preamble address cost/benefit measurement/tracking methodology, customer/contractor shared savings methodology, application examples and modernization opportunities. The MOU focuses on operational methodology in addressing and accomplishing modernization projects and contains the Core Document. The structured methodology described in the MOU establishes an umbrella approach to IMIP that is compatible with the multi-program environment. Additionally, the Master Contract satisfies baseline terms and conditions requirements through the use of a Core Document. This portion of the IMIP documentation contains the common nomenclature and application philosophy that is in all IMIP project applications. The document serves as an operational baseline umbrella over all IMIP activities.

## IMIP Clause

With common contractual and application elements addressed in the Core Document, the IMIP approach is tailored to specific program/modernization project needs and operating provisions through discrete IMIP clauses. The IMIP Master Contract includes a separate IMIP Clause for each program affected by the modernization effort. The individual clauses detail the operating provisions necessary and applicable to the corresponding subject programs.

## Document Flexibility

The reliance upon the Core Document to provide the common terminology and data requirements makes possible the creation of a living document that reacts to the contractor's changing environment. As IMIP projects are completed, their appropriate Individual Project Addendum can be deleted from the Master Contract. Likewise, when opportunities for new IMIP projects arise, they can be documented in individual Project Addenda and added to the Master Contract. In this fashion, the Master Contract facilitates a less tedious approach to IMIP project management.

## Individual Project Addendum

Since many individual modernization projects offer a synergistic benefit and thus, can impact multiple programs, the use of Individual Project Addenda is appropriate. A separate Individual Project Addendum for each project provides specific information as to investment, savings attributable to implementation, cost/benefit tracking, and other information.

## Cost-Benefit Measurement and Tracking

The success of an IMIP project often rests with the effectiveness of the Cost/Benefit Measurement/Tracking System used to manage the project and measure actual benefits gained. The measurement techniques that are applicable for measuring performance in the manufacturing function traditionally rely upon work measurement standards. While effective in the production area, this technique is costly, specialized, and cannot be universally applied to overhead and support functions. The multi-program environment and opportunities for modernization gains in nonmanufacturing areas create needs not met by traditional measurement/tracking methods.

The challenge faced in the multi-program environment is to measure total factory cost while maintaining a balance between the cost of measurement activity and the magnitude of the savings being measured. Simpler, less cost-intensive techniques have been developed for application in nonmanufacturing functions. Techniques such as "input:output" or "activity:indicator" ratios, as shown in Figure 4, are being used to provide reliable measurements at lower cost.

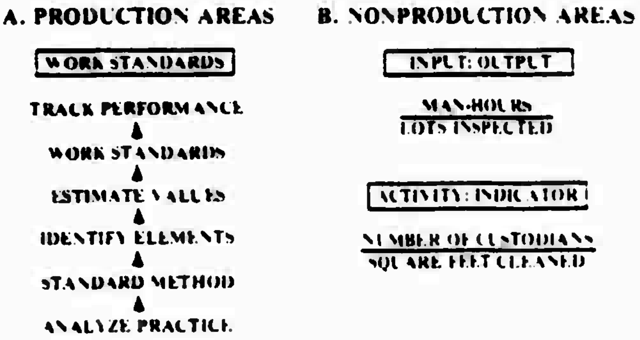



*Figure 4 Cost/Benefit Measurement/Tracking Techniques*

A comprehensive, yet flexible Cost/Benefit Measurement/Tracking System is a key element in the generic, multi-program approach to IMIP application. The proper selection of effective measurement techniques is essential to a valid portrayal of both AS-IS and TO-BE costs as well as benefits achieved. The measurement must be carefully selected to emphasize the major project impact area. Components of the measurement should be provided by an existing data collection system, thereby eliminating the need for the creation of costly and unique data bases. When selected in the proper manner, the measurements are not linked to detail component specification, but possess a generic property not achievable by linkage to specific part numbers or system characteristics. Examples of this generic measurement approach are provided in Figure 5.

| PROJECT | MEASUREMENT |
|---|---|
| OFFICE OF THE FUTURE | $ TECHNICAL PUBLICATIONS & REPRODUCTION / $ NAPD SALARIED LABOR COSTS |
| INVENTORY REDUCTION | $ AVERAGE WIP INVENTORY / $ ANNUAL SALES − CHANGE IN WIP |
| FLEXIBLE MANUFACTURING | $ COST OF SALES (AFFECTED PARTS) / $ AS-IS STANDARD HOURS |

*Figure 5 Examples of Measurements*

## Shared Savings Methodology

The generic measurement technique associated with cost/benefit tracking and shared savings determination employs measurements similar to those examples in Figure 5. The results from application of such measurement techniques are the essential input required to determine and allocate shared savings. Selection of the proper measurement is the first step in the process of properly determining cost/benefit values for a particular IMIP project and subsequent savings allocation. This progressive process is illustrated in Figure 6.

STEP 1 - SELECT A MEASUREMENT

STEP 2 - DEFINE BASELINE $\boxed{B}$

STEP 3 - MEASURE THE ACTUAL PERFORMANCE $\boxed{A}$

STEP 4 - CALCULATE % IMPROVEMENT:

$$M = \frac{B-A}{B} \times 100$$

STEP 5 - CALCULATE INCREMENTAL SAVINGS PER PERCENT IMPROVEMENT: I

STEP 6 - DETERMINE ACTUAL SAVINGS:

$$S = M \times I$$

STEP 7 - CALCULATE SHARED SAVINGS:

$$P = S \times F \quad \text{WHERE } F = \text{\% SHARE}$$

STEP 8 - SELECT ALLOCATION BASE

STEP 9 - ALLOCATE SAVINGS

| PROGRAM | A | B | C | TOTAL |
|---|---|---|---|---|
| ALLOCATION BASE % | 20 | 30 | 50 | 100 |
| PSR | 0.2P | 0.3P | 0.5P | P |

*Figure 6 Shared Savings Allocation Technique*

Establishment of a baseline that represents the reference point from which both technology improvement and time sequence are measured is the next essential step. Using this starting point, actual performance can be measured and the improvement calculated as a percentage improvement. The dollarized incremental impact of each percent change is calculated and used to determine total savings.

The savings identified in a multi-program environment must be apportioned to those programs impacted by the modernization. Hence, the selection of an allocation base that represents a measurable characteristic of the project. For example, an allocation base might be AS-IS standard hours, salaried labor cost, direct labor costs, etc. Once established, this allocation base is then applied to those programs impacted by the IMIP project to determine the appropriate savings share that each program must carry. This percentage allocation technique makes possible the recognition of the multiple program impact that is associated with total factory modernization.

To provide the required cash flow analysis, a DCF model is employed. Applicable to either capital intensive projects or those requiring little or no capital expenditures, the model takes into account incremental contractor cash flow arising from project implementation. Although differing project acceptability measures are used, the model provides a systematic examination of the impact of the project to both the buyer and seller. The computer generated model is shown in Figure 6A.

## IMIP Project Application

The generic technique for shared allocation, as described above, is applicable to two distinct IMIP project classifications. The first hypothetical example, Flexible Machining, is a Modernization Investment Project (MIP) classification. Non-capital-intensive projects, which are entitled Modernization Efficiency Projects (MEP), are represented by the second hypothetical example, Employee Benefits Alterations.

LTV AEROSPACE AND DEFENSE COMPANY
DISCOUNTED CASH FLOW R.O.I. ANALYSIS

PROJECT:

| YEAR: | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| PERIOD: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

SECTION I - INVESTMENT DATA
1. EQUIPMENT
2. BUILDING
3. OTHER
4. CAPITAL INVESTMENT SUBTOTAL
5. EXPENSES
6. TOTAL INVESTMENT

SECTION II - PROJECT CASH FLOW
7. PRODUCTIVITY SAVINGS REWARD
8. RETAINED PROGRAM SAVINGS
9. COMMERCIAL PROGRAM SAVINGS
10. TOTAL CONTRACTOR SAVINGS
11. COST OF MONEY RECOVERY
12. CAS 409 DEPRECIATION
13. EXPENSE RECOVERY
14. LOST PROFIT EFFECT
15. DEPRECIATION PROFIT
16. SALVAGE VALUE
17. BEFORE TAX CASH FLOW

SECTION III - TAX CALCULATIONS
18. ACRS DEPRECIATION
19. TAXABLE INCOME
20. INCOME TAX
21. INVESTMENT TAX CREDIT
22. EXPENSE TAX ADJUSTMENT
23. AFTER TAX CASH FLOW

SECTION IV - DOD BENEFIT SUMMARY
24. DOD PROGRAM BENEFIT (W/O INCENTIVE)
CUMULATIVE TOTAL
25. DOD PROGRAM BENEFITS (WITH INCENTIVE)
CUMULATIVE TOTAL
26. DOD FUNDING
CUMULATIVE TOTAL
27. DOD NET CASH FLOW
28. DOD CUMULATIVE CASH FLOW NET PRESENT VALUE
29. DOD PAYBACK PERIOD (YEARS)
30. DOD ROI
31. CASH FLOW RATIO
(DOD TO CONTRACTOR, CUMULATIVE)

SECTION V - CONTRACTOR BENEFIT SUMMARY
32. CUMULATIVE CASH FLOW NET PRESENT VALUE
33. RATE OF RETURN W/O INCENTIVE
34. RATE OF RETURN WITH INCENTIVE
35. PAYBACK PERIOD (YEARS)
36. INVESTMENT COST TO SAVINGS RATIO

DATA INPUTS

DOD FUNDING

EXPENDITURES:
EQUIPMENT CAPITAL
EQUIPMENT SALVAGE VALUE
BUILDING CAPITAL
OTHER CAPITAL
OTHER SALVAGE VALUE
EXPENSES

SAVINGS:
DOD SAVINGS
MAJOR PROGRAM SAVINGS
RETAINED PROGRAM SAVINGS
COMMERCIAL SAVINGS
FIRST YEAR OF FULL SAVINGS

CONTRACTOR ANALYSIS FACTORS:
% SHARED SAVINGS
% PROFIT
% GOVERNMENT BUSINESS
TAX RATE
ITC RATE
DISCOUNT RATE
CAS 414 RATE

CONTRACTOR DEPRECIATION:

CAS 409 DEPRECIATION -
DEPRECIATION METHOD ......................
(1:STRAIGHT LINE; 2:SUM-OF-YEARS; 3:SUM-OF-YEARS/HALF-YEAR;
4:150% DECLINING BALANCE; 5:150% DB,SWITCH TO ST LINE)
ASSET SERVICE LIFE (YEARS)—
EQUIPMENT..............................
BUILDING..............................
OTHER..............................
YEAR PLACED INTO SERVICE................
ACRS DEPRECIATION -
DEPRECIATION METHOD......................
(1:STANDARD ACRS TABLES; 2:STRAIGHT LINE)
ASSET CLASS (SERVICE LIFE).... (3:3-YR; 5:5-YR; 10:10-YR) —
EQUIPMENT..............................
BUILDING..............................
OTHER..............................
YEAR PLACED INTO SERVICE................

FIGURE 6A Discounted Cash Flow R.O.I. Analysis

## Modernization Investment Project - A Practical Example

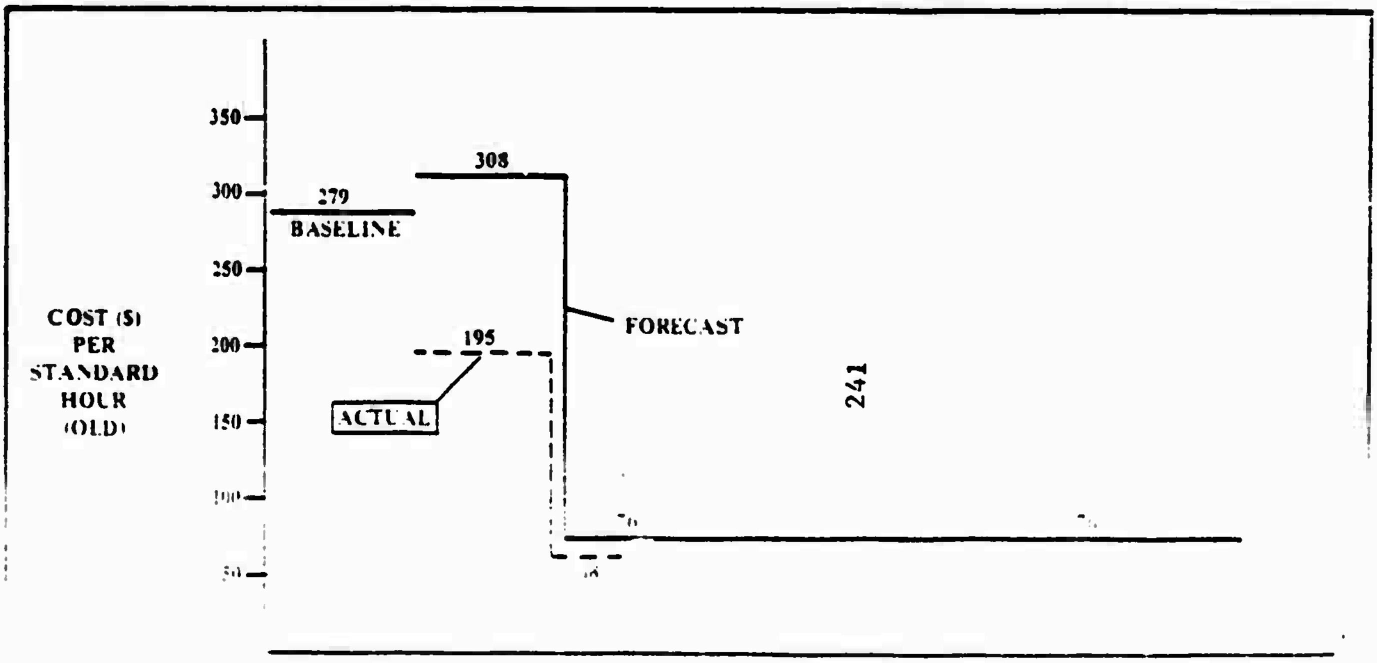
Our production-oriented modernization project (MIP) example is Flexible Machining. This project is capital intensive and entails an investment of approximately $10 million. The benefits associated with the project are realized from the labor savings for automated, computer-controlled fabrication versus stand-alone, three-axis and four-axis conventional fabrication.

Since this project pertains to production efforts, the selected allocation based is standard hours. This selection sets the determinate factor used in the shared savings analysis. The project's selected measurement then becomes:

**$ COST OF SALES OF AFFECTED PARTS PER AS-IS STANDARD HOUR**

IMIP incentives are based on actual results, hence the calculation of the first six months' shared savings is based on the actual experience illustrated in Figure 7 and shown below:

| | |
|---|---|
| STANDARD-HOURS | 12,494 |
| DIRECT PRODUCTION HOURS | 20,726 |
| TOTAL COST | $2,430,496 |
| COST PER STANDARD HOUR | $194.53 |



Using the previously described elemental allocation technique, the shared savings associated with actual performance in the MIP example are developed. A summary of the shared savings allocation determination is provided in Figure 8.

| DESCRIPTION | VALUE | | |
|---|---|---|---|
| 1. DEFINE MEASUREMENT | (\$) COST OF AFFECTED PARTS / AS-IS STANDARD HOURS | | |
| 2. DEFINE BASELINE | \$279/STANDARD HOUR | | |
| 3. MEASURE ACTUAL PERFORMANCE | \$195/STANDARD HOUR | | |
| 4. DETERMINE % IMPROVEMENT | 30% | | |
| 5. CALCULATE INCREMENTAL SAVINGS PER % IMPROVEMENT | \$35,000 | | |
| 6. ACTUAL SAVINGS DETERMINATION | 30 × \$35,000 = \$1,050,000 | | |
| 7. SHARED SAVINGS | 0.50 × \$1,050,000 = \$525,000 | | |
| 8. ALLOCATION BASE | STANDARD HOURS | | |
| 9. PROGRAM ALLOCATION | | | |
| PROGRAM | A | B | C |
| STANDARD HOURS | 30,000 | 13,000 | 7,000 |
| ALLOCATION (%) | 61 | 26 | 13 |
| SAVINGS | \$320,000 | \$137,000 | \$68,000 |

*Figure 8 MIP Example - Shared Savings Allocation*

The cash flow associated with the shared savings allocation calculated for the MIP example is presented in Figure 9. Shown are both the contractor and government cash flows over the sharing period. In the figure, the solid line indicates the forecasted savings flow that would result in a 50-percent return on investment (ROI) in the seventh year, at which time the sharing agreement is terminated. The dashed line represents actual experience that was better than that forecasted. Hence, a positive cash flow results that can yield an accelerated time frame from which the contractor would realize a 50-percent ROI. This accelerated cash flow would probably truncate the projected seven-year sharing period to a shorter time span.

MEMO: STANDARD HOUR PER YEAR = 50,000 AT 70% CAPACITY
COST IMPROVEMENT AT $100 PER STANDARD HOUR =
$9.4M PER YEAR

| | ($M) CONTRACTOR | GOVERNMENT |
|---|---|---|
| YEAR 1: STARTUP COST ABOVE BASE | (1.45) | — |
| YEAR 2: COST IMPROVEMENT AT 50% SHARING | 4.7 | 4.7 |
| PROFIT REDUCTION | (1.1) | 1.1 |
| VENDOR PAYMENT | (10) | — |
| YEAR 3 THROUGH YEAR 7: COST IMPROVEMENT | 4.7 | 4.7 |
| PROFIT REDUCTION | (1.1) | 1.1 |

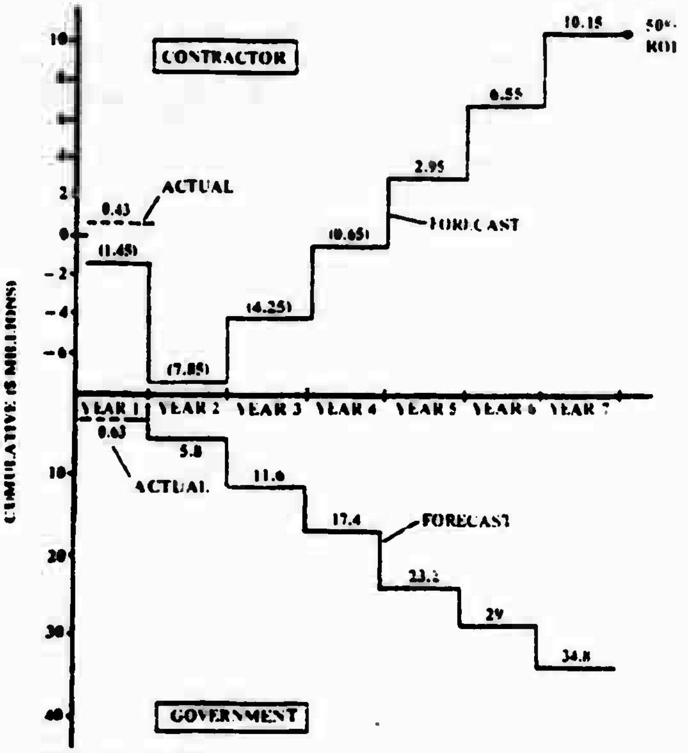



*Figure 9 MIP Example - Cash Flow*

## Modernization Efficiency Project - A Practical Example

The hypothetical nonproduction modernization project (MEP) example relates to employee fringe benefits. This MEP is a non-capital-intensive project, since it requires no capital investment. The cost benefits of project implementation are derived from a shift in the health care benefit coverage from traditional insurance to health-maintenance-organization-type coverage.

Alterations in benefit coverage in the first year result in lower fringe benefit costs. Since fringe benefit costs are directly related to changes in labor costs, the selected allocation base for this project is labor dollars. The measurement selected for this project then becomes:

FRINGE BENEFIT COST AS % OF LABOR COST
OR

$$\frac{\text{FRINGE BENEFIT \$}}{\text{LABOR \$}}$$

Historical analysis of fringe benefit cost yields measurement data and a forecasted value for future years. This information is presented in graphic format in Figure 10. The baseline value is plotted prior to project implementation and the forecasted value tracks activity following project implementation. Actual experience for the first year indicates a favorable trend in fringe benefit cost reduction. Tracking against the selected measurement yields a value of 14.4 percent.

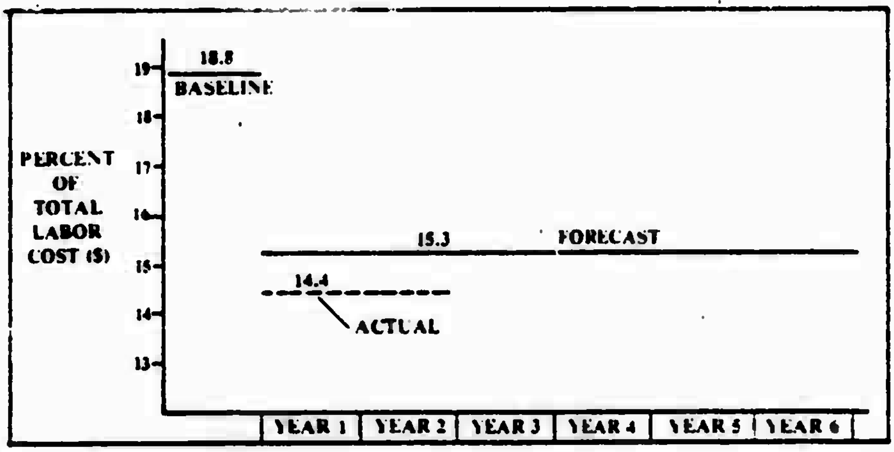



*Figure 10 MEP Example – Actual Experience and Forecast*

Using the previously described elemental technique, the shared savings associated with actual performance in the MEP example are developed. A summary of the shared savings allocation determination is provided in Figure 11.

| DESCRIPTION | VALUE |
|---|---|
| 1. DEFINE MEASUREMENT | FRINGE BENEFIT $ / LABOR $ |
| 2. DEFINE BASELINE | 18.8% |
| 3. MEASURE ACTUAL PERFORMANCE | 14.4% |
| 4. DETERMINE % IMPROVEMENT | 4.4% |
| 5. CALCULATE INCREMENTAL SAVINGS PER % IMPROVEMENT | $2,700,000 |
| 6. ACTUAL SAVINGS DETERMINATION | 4.4 x $2,700,000 = $12,000,000 |
| 7. SHARED SAVINGS | 0.50 x $12,000,000 = $6,000,000 |
| 8. ALLOCATION BASE | LABOR COST |
| 9. PROGRAM ALLOCATION | |

| PROGRAM | A | B | C | D |
|---|---|---|---|---|
| LABOR COST ($ x 1000) | [illegible] | [illegible] | [illegible] | [illegible] |
| ALLOCATION (%) | [illegible] | [illegible] | [illegible] | [illegible] |
| SAVINGS ($ x 1000) | [illegible] | [illegible] | [illegible] | [illegible] |

[illegible]

## Total Factory Modernization and IMIP

Contractor expertise in developing and using IMIP is still evolving. As practical contractor experience matures, recognizing potential IMIP opportunities will be essential for modernizing the total factory and reducing the government's procurement costs. The flexible, generic approach of IMIP application to total factory modernization can be the tool that maximizes the impact of contractors' modernization efforts. This generic approach is key because it is structured to include nonmanufacturing function applications as potential opportunities.

The use of this generic IMIP approach can provide simple, cost-effective techniques for implementing modernization projects affecting shop-floor, as well as above-the-shop-floor functions and related costs. To successfully and effectively participate in IMIP-sponsored projects that will benefit both contractor and customer, careful planning and a proven operational system are required for project cost management, cost/benefit measurement/tracking, and shared savings allocation. The generic approach can be a cost-effective component of an IMIP application.

MULTI-CRITERIA PERFORMANCE MEASUREMENT
AT VOUGHT AERO PRODUCTS

Vought Aero Products Division has used measurements in the "production area" for many years. Panel charts have been used for graphic display of trends in performance. However, production costs and their proportional ratio to total costs have progressively declined. Due to changes in technology, the cost driver dominance has shifted from production to support and overhead functions as illustrated in Figure 1.

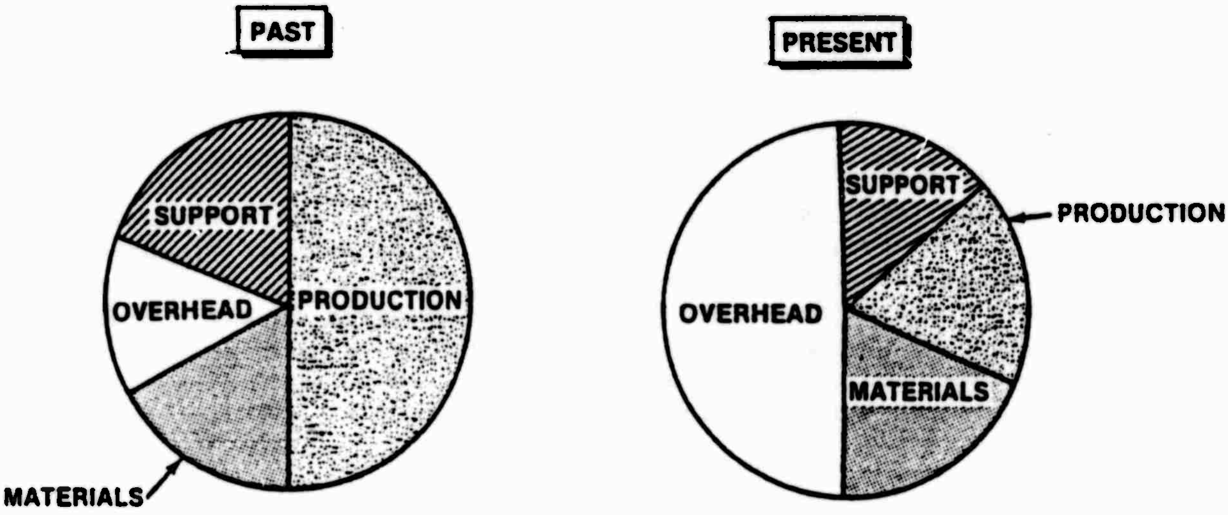



FIGURE 1 CHANGE IN COST DRIVERS

The modification of the cost structure, along with competitive pressures, has created the need to address both production and non-production costs. A system is being implemented to expand the application of measurements to the non-production areas of the division.

## Cost-Effectiveness

Measurements are essential for establishing controlls and accountability. More importantly, measurements provide a valuable management tool because they make performance visible. Industry has recognized these attributes and has used different approaches to monitor and develop measurements.

The traditional method of measuring performance in the production function involves the use of work standards. Such standards are developed by a cost intensive, analytical, multi-step method, as depicted in Figure 2A. While effective in the production area, this technique is costly, specialized, and cannot be universally applied to overhead and support functions.

**A. PRODUCTION AREAS**

WORK STANDARDS

TRACK PERFORMANCE
↑
WORK STANDARDS
↑
ESTIMATE VALUES
↑
IDENTIFY ELEMENTS
↑
STANDARD METHOD
↑
ANALYZE PRACTICE

**B. NONPRODUCTION AREAS**

INPUT:OUTPUT

- $\frac{\text{MAN-HOURS}}{\text{LOTS INSPECTED}}$

ACTIVITY:INDICATOR

- $\frac{\text{NUMBER OF CUSTODIANS}}{\text{SQUARE FEET CLEANED}}$

Figure 2 Measurement Techniques

Other simpler and less cost-intensive techniques have been developed for application in non-production functions. Techniques such as "input-output" or "activity:indicator" ratios, as shown in Figure 2B, have been utilized to provide reliable measurement at a lower cost. Managers in the non-production areas have used these techniques to select their own measurements. Approved measurements have been published and updated in the reference manual entitled, Productivity Program Status, which is issued by IMOD to all department managers.

The following ground rules have been used to keep the measurement system cost-effective:

- Each function, as listed in Table 1, must have an approved set of measurements.
- Within each function, only one measurement is required for each department.
- Measurement data are collected and reported once each quarter.

| FUNCTIONS | |
|---|---|
| • ENGINEERING | • MATERIALS |
| • FACILITIES | • MANUFACTURING ENGINEERING |
| • LOGISTICS | • QUALITY ASSURANCE |
| • HUMAN RESOURCES | • MANUFACTURING CONTROL |
| • FINANCE | • INDUSTRIAL MODERNIZATION |
| • PROGRAMS & MARKETING | • DATA PROCESSING |
| | • OVERHAUL & MAINTENANCE |

**FUNCTIONS AND DEPARTMENTS**

DIVISION

FUNCTION — FUNCTION

DEPARTMENT DEPARTMENT — DEPARTMENT DEPARTMENT

TABLE 1 FUNCTIONS AND DEPARTMENTS

## Method

The method can best be illustrated by an example. For reference, we assume an idealized function called, "GENERAL," which has two departments, "ADMINISTRATION" and "OPERATION." Each department has a measurement:

- ADMINISTRATION - Administration Costs/Total Costs
- OPERATION - Man-Hours/Units Produced

| | QUARTER | | | |
|---|---|---|---|---|
| MEASUREMENTS | 1 | 2 | 3 | 4 |
| ADMINISTRATION COSTS | 7.0 | 7.0 | 6.0 | 6.0 |
| TOTAL COSTS ($000) | 1.00.0 | 100.0 | 100.0 | 100.0 |
| MAN-HOURS | 69.0 | 50.0 | 60.0 | 63.0 |
| UNITS PRODUCED | 100.0 | 100.0 | 100.0 | 100.0 |

Figure 3 Quarterly Data Input Form

Measurement data is collected through a Quarterly Data Input Form, as shown in Figure 3; and a Measurement Characteristics Form, as depicted in Figure 4. The first form is used to collect quarterly actuals. The second form assigns a relative weight to each measurement. Any measurement, for which quarterly data is not supplied, automatically earns the "worst case" performance and rating.

| MEASUREMENTS | WEIGHT | PRODUCTIVITY IMPROVEMENT (PERCENT) |
|---|---|---|
| ADMINISTRATION COSTS<br>TOTAL COSTS | 1.0 | 4.0 |
| MAN-HOURS<br>UNITS PRODUCED | 9.0 | 4.0 |

Figure 4 Measurement Characteristics Form

The specified potential range of performance, from "best case" to "worst case", is calculated in a uniform manner for each measurement. To achieve division-wide uniformity in ratings, these limits are derived from the average performance in the "base year".

Best Case: 60% better than "base year" performance
Worst Case: 40% worse than "base year" performance

The performance-rating relationship is described in Figure 4A.

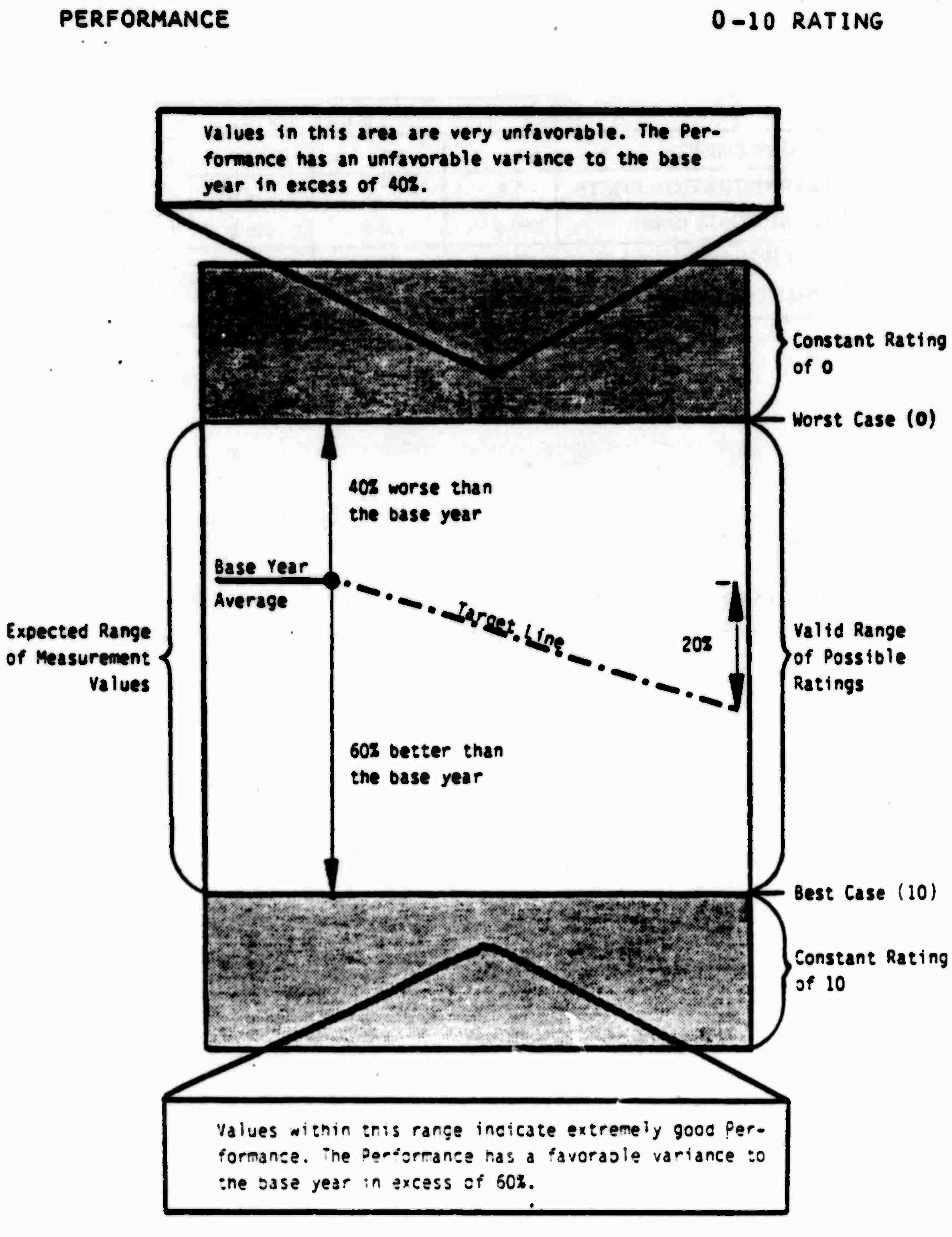



Figure 4A - Performance and Rating Relationship

Department-level performance is reported for each measurement in charts, as illustrated in Figures 5 and 6. These charts feature two sections, denoted as PERFORMANCE and RATING. The performance shown pertains to the individual measurement. Since measurements are often diverse and cannot be mathematically added, ratings are used to convert all performances to a common scale of 0 ("Worst Case") to 10 ("Best Case"). Such a conversion allows comparison between diverse measurements, as well as the calculation of a function's total performance.

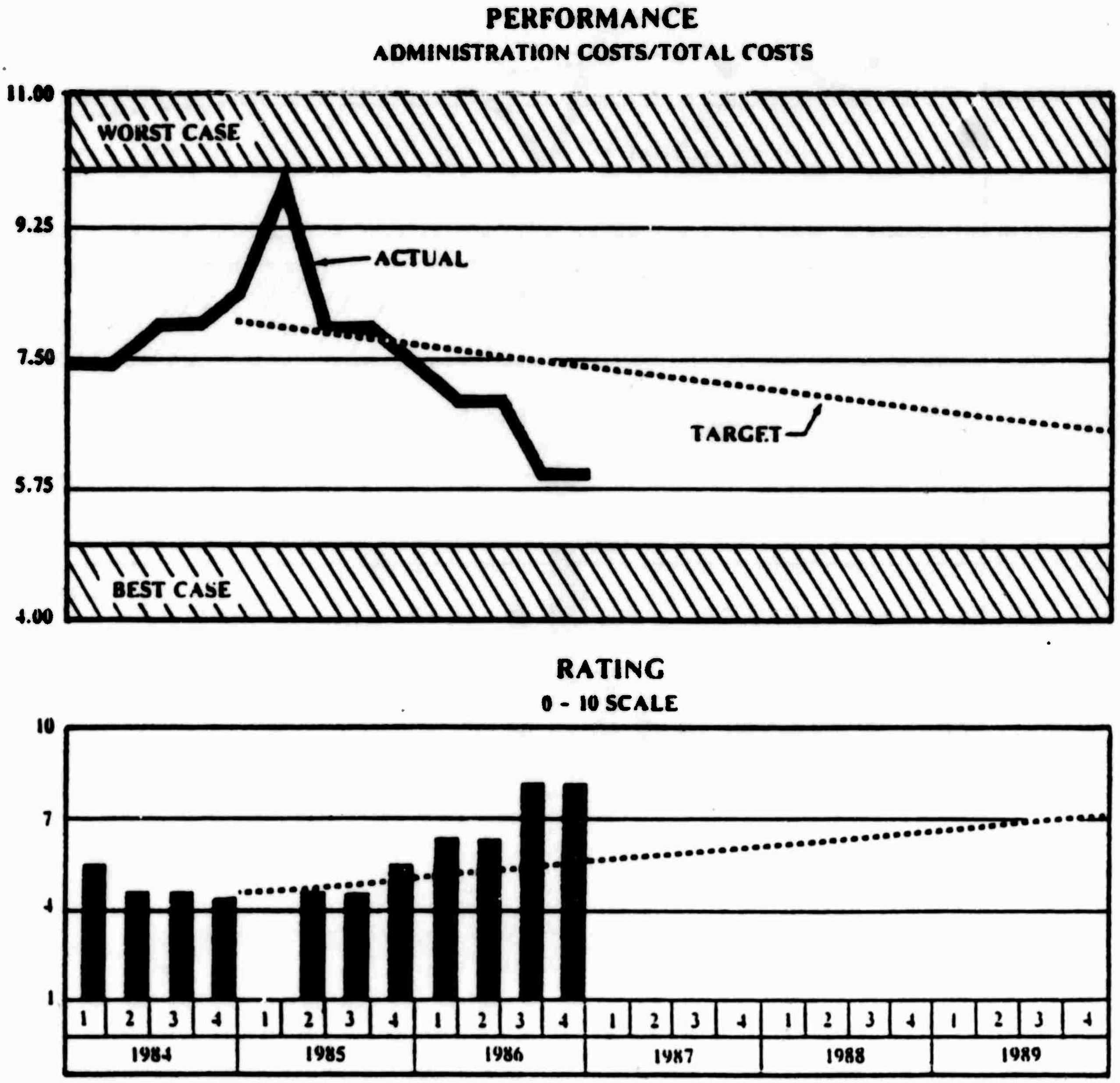



Figure 5 Department-Level Performance
ADMINISTRATION

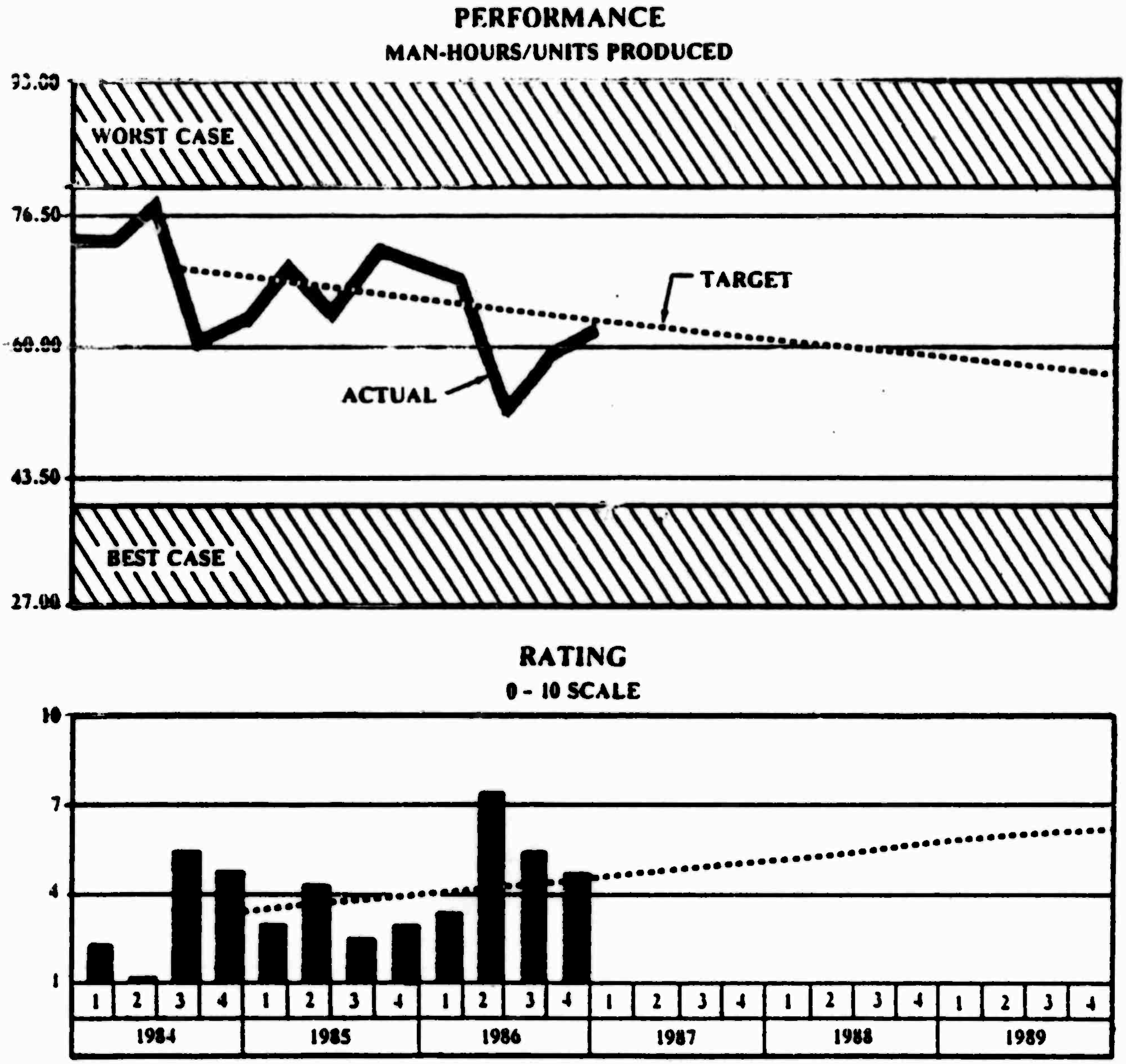



Figure 5 Department-Level Performance - OPERATION

Quarterly results are reported in detail in the Present Quarter Status Report, which is shown in Table II. This report provides a summary of the last quarter's target performance, actual performance and ratings for all measurements in the function. Target performance is generally identical to the Vought Aero Products Division's commitment for productivity improvement. That is, a commitment to improve annual productivity by "X" percent requires the same "X" percent annual improvement in the performance target.

| FUNCTION: GENERAL | PERFORMANCE | | PERFORMANCE LIMITS | | RATING | | |
|---|---|---|---|---|---|---|---|
| MEASUREMENT | TARGET (A) | ACTUAL (B) | BEST (10) (C) | WORST (0) (D) | 1 - 10 RATING (E) | WEIGHT (F) | *WEIGHTED RATING (G) |
| ADMINISTRATION | | | | | | | |
| ADMINISTRATION COSTS / TOTAL COSTS (PERCENT) | 7.391 | 6.000 | 5.000 | 10.000 | 8.20 | 1.00 | 0.82 |
| | | | DEPARTMENT RATING: | | 8.20 | | |
| OPERATION | | | | | | | |
| MAN-HOURS / UNITS PRODUCED | 63.052 | 63.000 | 40.000 | 80.000 | 4.82 | 9.00 | 4.34 |
| | | | DEPARTMENT RATING: | | 4.82 | | |
| | | | TOTAL RATING: | | | 10.00 | 5.16 |

* - WEIGHTED RATING = (F) X (E) 10

TABLE II PRESENT QUARTER STATUS REPORT

A function's total performance is a weighted aggregate of department-level performances. This aggregate is calculated by assigning a relative "weight" to each measurement. The relative weights are generally proportional to departmental budgets. Function-level performance for GENERAL is shown in Figure 7. GENERAL'S total rating and the contribution of each department to this rating are also shown.

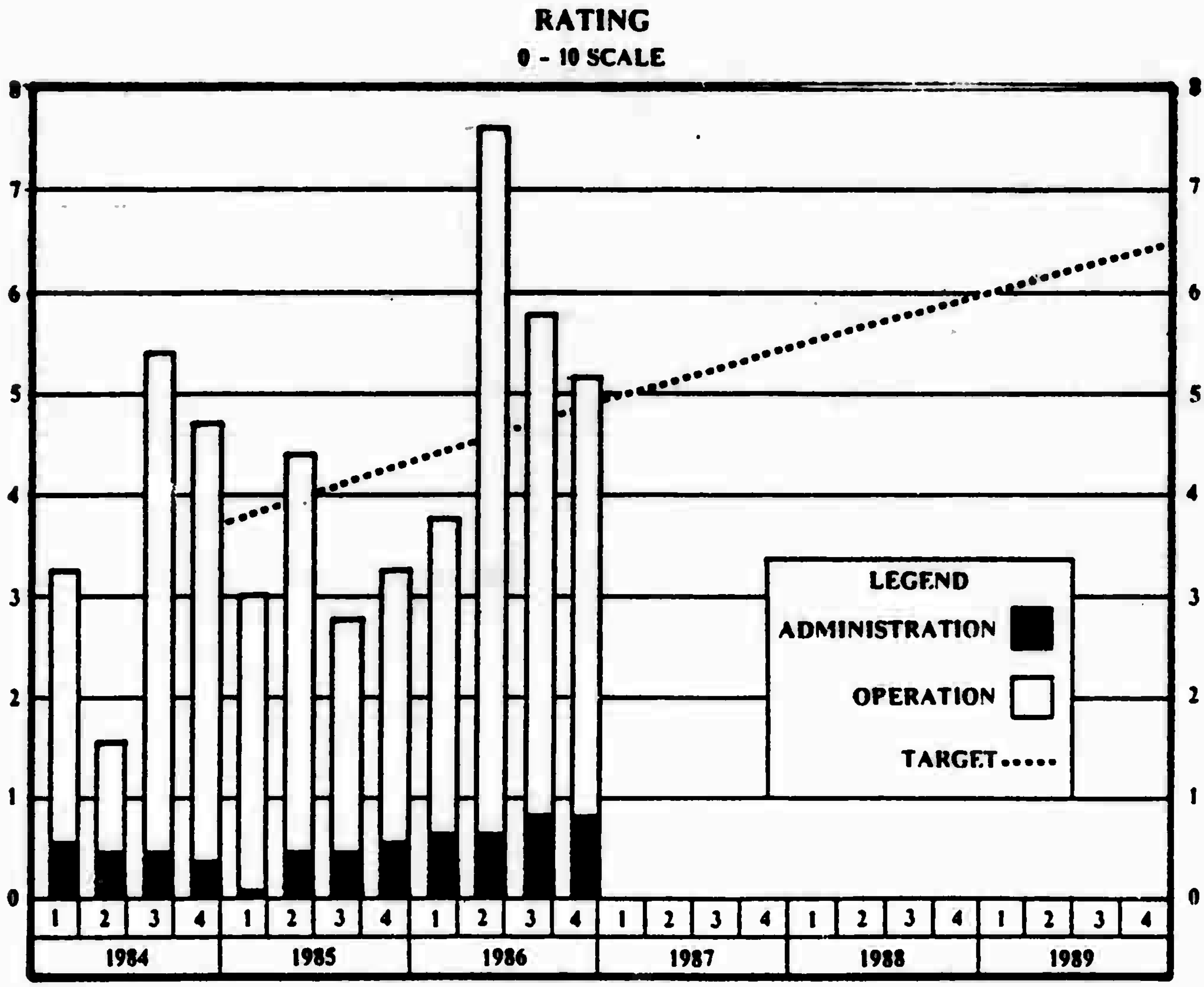



FIGURE 7 Function-Level Performance - GENERAL

## Relationship with Budgets

Measurements are created to serve two objectives:

- Monitor performance improvement
- Provide cost trends for future bids and proposals.

To meet these objectives, selected measurements must mathematically relate to departmental budgets. The mathematical relationship is possible because each department has chosen a parameter that is common to both measurement and budget, as Table III highlights.

| MEASUREMENT | BUDGET |
|---|---|
| ADMINISTRATION | |
| $\frac{\text{Administration Costs}}{\text{Total Costs}}$ $\boxed{\%}$ | Total Costs X $\boxed{\%}$ = Administration Costs |
| OPERATIONS | |
| $\boxed{\text{Man-Hours/Units}}$ Produced | Units Produced<br>X $\boxed{\text{Man-Hours/Unit}}$<br>X \$ per Man-Hour<br>= Budget |

TABLE III RELATIONSHIP OF PARAMTERS
IN MEASUREMENTS AND BUDGETS

## Implementation

The computer software for the measurement system has been developed on the IBM 3081 mainframe computer. The essential measurement selection process involves department managers in functional areas selecting measurements for use in their areas. Throughout the measurement selection and performance reporting, a single coordinating group - the Industrial Modernization Group, is responsible for assuring uniformity of system application and on-going system maintenance. VAPD has now positioned itself to take advantage of the cost savings opportunities made available through implementation of an effective multi-criteria performance measurement system in non-production areas.

# TOTAL FACTOR PRODUCTIVITY MODEL

IMOD UNIT 2-20170
NOVEMBER 1985

# TOTAL FACTOR PRODUCTIVITY

$$\text{PROFITABILITY} = \frac{\text{SALES}}{\text{COST}} = \frac{\text{PRODUCT QUANTITY}}{\text{RESOURCE QUANTITY}} \times \frac{\text{PRODUCT PRICE}}{\text{RESOURCE PRICE}}$$

$$\text{PROFITABILITY} = \text{PRODUCTIVITY} \times \text{PRICE RECOVERY}$$

## TOTAL FACTOR PRODUCTIVITY

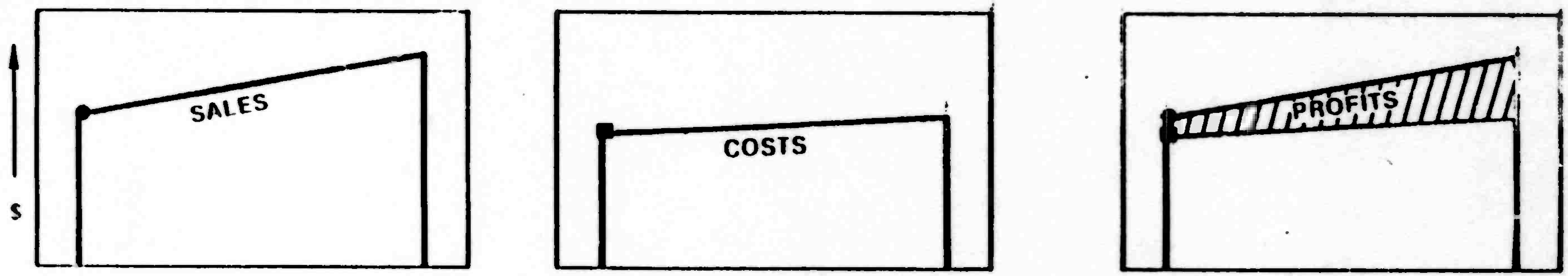
A MATHEMATICAL RELATIONSHIP EXISTS BETWEEN PROFITABILITY, PRODUCTIVITY, AND PRICE RECOVERY.

PRODUCTIVITY

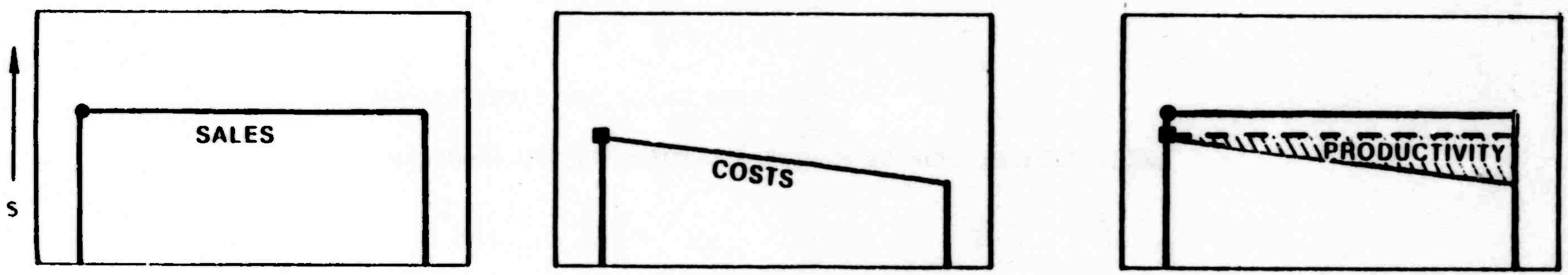
LTV Aerospace and Defense
Vought Aero Products Division

# MATHEMATICAL MODEL OF PRODUCTIVITY

CURRENT $ - WITH INFLATION




CONSTANT $ - WITHOUT INFLATION




TIME

## ESSENTIAL PRODUCTIVITY PARAMETERS

SALES | COSTS OR BUDGETS | INFLATION

P1 1212 34

## MATHEMATICAL MODEL OF PRODUCTIVITY

- SALES, COSTS, AND PROFITS ARE INFLUENCED BY PRODUCTIVITY.
- INFLATED "CURRENT DOLLARS" MASK THE INFLUENCE OF PRODUCTIVITY.
- USING "CURRENT DOLLARS", THE VARIANCE BETWEEN SALES AND COSTS MEASURES PROFITS.
- WHEN COMPARING DEFLATED "CONSTANT DOLLARS", CHANGES IN PRODUCTIVITY BECOME APPARENT.
- SALES, COSTS (OR BUDGETS), AND INFLATION ARE PARAMETERS ESSENTIAL TO MEASURING CHANGES IN "TOTAL PRODUCTIVITY".

PRODUCTIVITY

LTV Aerospace and Defense
Vought Aero Products Division

DIVISIONAL BUDGETS

FORECAST, $ MILLIONS

| | BASE YEAR | BASE YEAR + 1 | | | | |
|---|---|---|---|---|---|---|
| | ACTUAL | JANUARY | APRIL | JULY | OCTOBER | ACTUAL |
| **CURRENT DOLLARS** | | | | | | |
| SALES | 100 | 130 | 160 | 160 | 150 | 150 |
| INVENTORY | 80 | 110 | 100 | 100 | 110 | 110 |
| CHANGE IN INVENTORY | 20 | 30 | 20 | 20 | 30 | 30 |
| OUTPUT* | 120 | 160 | 180 | 180 | 180 | 180 |
| COSTS ( BUDGET ) | 110 | 144 | 166 | 161 | 161 | 161 |
| **INFLATION** | | | | | | |
| OUTPUT | BASE | <---<---<---<---<---<--- | | 3.0% | --->--->--->--->---> | |
| COSTS | BASE | <---<---<---<---<---<--- | | 5.0% | --->--->--->--->---> | |
| **CONSTANT DOLLARS** | | | | | | |
| OUTPUT | 120 | 155 | 175 | 175 | 175 | 175 |
| COSTS | 110 | 137 | 158 | 154 | 154 | 154 |
| COSTS/OUTPUT | 91.7% | 88.0% | 90.3% | 88.0% | 88.0% | 88.0% |
| **PRODUCTIVITY IMPROVEMENT** | | | | | | |
| TARGET | BASE | >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>> | | | | 3.0% |
| FORECAST | BASE | 4.0% | 1.5% | 4.0% | 4.0% | 4.0% |

## DIVISIONAL BUDGETS

BASE YEAR -- ACTUAL VALUES

- OUTPUT = SALES + CHANGE IN INVENTORY
- INFLATION IS NOT A FACTOR IN BASE YEAR VALUES.
- THE GOAL IS TO REDUCE "COSTS/OUTPUT" IN FUTURE YEARS.

**PRODUCTIVITY**

LTV Aerospace and Defense
Vought Aero Products Division

## DIVISIONAL BUDGETS

| | BASE YEAR | FORECAST, $ MILLIONS | | | | |
|---|---|---|---|---|---|---|
| | | BASE YEAR + 1 | | | | |
| | ACTUAL | JANUARY | APRIL | JULY | OCTOBER | ACTUAL |
| **CURRENT DOLLARS** | | | | | | |
| SALES | 100 | 130 | 160 | 160 | 150 | 150 |
| INVENTORY | 80 | 110 | 100 | 100 | 110 | 110 |
| CHANGE IN INVENTORY | 20 | 30 | 20 | 20 | 30 | 30 |
| OUTPUT* | 120 | 160 | 180 | 180 | 180 | 180 |
| COSTS ( BUDGET ) | 110 | 144 | 166 | 161 | 161 | 161 |
| **INFLATION** | | | | | | |
| OUTPUT | BASE | <---<---<---<---<---<--- | | 3.0% | --->--->--->--->---> | |
| COSTS | BASE | <---<---<---<---<---<--- | | 5.0% | --->--->--->--->---> | |
| **CONSTANT DOLLARS** | | | | | | |
| OUTPUT | 120 | 155 | 175 | 175 | 175 | 175 |
| COSTS | 110 | 137 | 158 | 154 | 154 | 154 |
| COSTS/OUTPUT | 91.7% | 88.0% | 90.3% | 88.0% | 88.0% | 88.0% |
| **PRODUCTIVITY IMPROVEMENT** | | | | | | |
| TARGET | BASE | >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>> | | | | 3.0% |
| FORECAST | BASE | 4.0% | 1.5% | 4.0% | 4.0% | 4.0% |

## DIVISIONAL BUDGETS

BASE YEAR + 1 -- JANUARY FORECAST

- BOTH OUTPUT AND COSTS ARE GREATER THAN FOR THE BASE YEAR IN CURRENT AND CONSTANT DOLLARS.
- COSTS/OUTPUT HAS DECREASED.
- FORECASTED ANNUAL PRODUCTIVITY IMPROVEMENT EXCEEDS TARGET.
- THE GOAL IS TO MEET FORECASTED ANNUAL IMPROVEMENT.

PRODUCTIVITY

LTV Aerospace and Defense
Vought Aero Products Division

## DIVISIONAL BUDGETS

| | BASE YEAR | FORECAST, $ MILLIONS | | | | |
|---|---|---|---|---|---|---|
| | | BASE YEAR + 1 | | | | |
| | ACTUAL | JANUARY | APRIL | JULY | OCTOBER | ACTUAL |
| **CURRENT DOLLARS** | | | | | | |
| SALES | 100 | 130 | 160 | 160 | 150 | 150 |
| INVENTORY | 80 | 110 | 100 | 100 | 110 | 110 |
| CHANGE IN INVENTORY | 20 | 30 | 20 | 20 | 30 | 30 |
| OUTPUT* | 120 | 160 | 180 | 180 | 180 | 180 |
| COSTS ( BUDGET ) | 110 | 144 | 166 | 161 | 161 | 161 |
| **INFLATION** | | | | | | |
| OUTPUT | BASE | <---<---<--- | <---<---<-- | 3.0% | --->--->--- | >--->---> |
| COSTS | BASE | <---<---<--- | <---<---<-- | 5.0% | --->--->--- | >--->---> |
| **CONSTANT DOLLARS** | | | | | | |
| OUTPUT | 120 | 155 | 175 | 175 | 175 | 175 |
| COSTS | 110 | 137 | 158 | 154 | 154 | 154 |
| COSTS/OUTPUT | 91.7% | 88.0% | 90.3% | 88.0% | 88.0% | 88.0% |
| **PRODUCTIVITY IMPROVEMENT** | | | | | | |
| TARGET | BASE | >>>>>>>>> | >>>>>>>>>>> | >>>>>>>>>>> | >>>>>>>>>>> | >>>>>>> 3.0% |
| FORECAST | BASE | 4.0% | 1.5% | 4.0% | 4.0% | 4.0% |

DIVISIONAL BUDGETS

BASE YEAR + 1 -- APRIL REVISED FORECAST

- BOTH OUTPUT AND COSTS HAVE INCREASED OVER JANUARY IN CURRENT AND CONSTANT DOLLARS.
- COSTS HAVE INCREASED MORE THAN OUTPUT.
- COSTS/OUTPUT HAS INCREASED OVER JANUARY.
- FORECASTED ANNUAL PRODUCTIVITY IMPROVEMENT IS BELOW TARGET.
- CHALLENGE BUDGETS ARE IMPLEMENTED.

## DIVISIONAL BUDGETS

| | BASE YEAR | FORECAST, $ MILLIONS BASE YEAR + 1 | | | | |
|---|---|---|---|---|---|---|
| | ACTUAL | JANUARY | APRIL | JULY | OCTOBER | ACTUAL |
| **CURRENT DOLLARS** | | | | | | |
| SALES | 100 | 130 | 160 | 160 | 150 | 150 |
| INVENTORY | 80 | 110 | 100 | 100 | 110 | 110 |
| CHANGE IN INVENTORY | 20 | 30 | 20 | 20 | 30 | 30 |
| OUTPUT* | 120 | 160 | 180 | 180 | 180 | 180 |
| COSTS ( BUDGET ) | 110 | 144 | 166 | 161 | 161 | 161 |
| **INFLATION** | | | | | | |
| OUTPUT | BASE | <---<---<---<---<---<--- | | 3.0% | --->--->--->--->---> | |
| COSTS | BASE | <---<---<---<---<---<--- | | 5.0% | --->--->--->--->---> | |
| **CONSTANT DOLLARS** | | | | | | |
| OUTPUT | 120 | 155 | 175 | 175 | 175 | 175 |
| COSTS | 110 | 137 | 158 | 154 | 154 | 154 |
| COSTS/OUTPUT | 91.7% | 88.0% | 90.3% | 88.0% | 88.0% | 88.0% |
| **PRODUCTIVITY IMPROVEMENT** | | | | | | |
| TARGET | BASE | >>>>>>>>>>>>>>>>>>>> | >>>>>>>>>>>> | >>>>>>>>>>>> | >>>>>>>>>>>>>>>>> | 3.0% |
| FORECAST | BASE | 4.0% | 1.5% | 4.0% | 4.0% | 4.0% |

## DIVISIONAL BUDGETS

BASE YEAR + 1 -- JULY REVISED FORECAST

- OUTPUT HAS REMAINED AT THE APRIL LEVEL.
- BUDGET HAS BEEN REDUCED DUE TO CHALLENGE BUDGETS.
- COSTS/OUTPUT HAS DECREASED TO JANUARY LEVELS.
- FORECASTED ANNUAL PRODUCTIVITY IMPROVEMENT HAS INCREASED TO JANUARY LEVELS.

PRODUCTIVITY

LTV Aerospace and Defense
Vought Aero Products Division

## DIVISIONAL BUDGETS

FORECAST, $ MILLIONS

| | BASE YEAR | BASE YEAR + 1 | | | | |
|---|---|---|---|---|---|---|
| | ACTUAL | JANUARY | APRIL | JULY | OCTOBER | ACTUAL |
| **CURRENT DOLLARS** | | | | | | |
| SALES | 100 | 130 | 160 | 160 | 150 | 150 |
| INVENTORY | 80 | 110 | 100 | 100 | 110 | 110 |
| CHANGE IN INVENTORY | 20 | 30 | 20 | 20 | 30 | 30 |
| OUTPUT* | 120 | 160 | 180 | 180 | 180 | 180 |
| COSTS ( $\boxed{\text{BUDGET}}$ ) | 110 | $\boxed{144}$ | $\boxed{166}$ | $\boxed{161}$ | $\boxed{161}$ | 161 |
| **INFLATION** | | | | | | |
| OUTPUT | BASE | <---<---<--- | <---<---<--- | 3.0% | --->---> | --->---> |
| COSTS | BASE | <---<---<--- | <---<---<--- | 5.0% | --->---> | --->---> |
| **CONSTANT DOLLARS** | | | | | | |
| OUTPUT | 120 | 155 | 175 | 175 | 175 | 175 |
| COSTS | 110 | 137 | 158 | 154 | 154 | 154 |
| COSTS/OUTPUT | 91.7% | 88.0% | 90.3% | 88.0% | 88.0% | 88.0% |
| **PRODUCTIVITY IMPROVEMENT** | | | | | | |
| TARGET | BASE | >>>>>>>>>> | >>>>>>>>>> | >>>>>>>>>> | >>>>>>>>>> | >>>>>> 3.0% |
| FORECAST | BASE | 4.0% | 1.5% | 4.0% | 4.0% | 4.0% |

## DIVISIONAL BUDGETS

BASE YEAR + 1 -- OCTOBER REVISED FORECAST

- OUTPUT AND COSTS HAVE HELD AT JULY LEVELS.
- COSTS/OUTPUT HAS HELD AT THE JANUARY LEVEL.
- FORECASTED ANNUAL PRODUCTIVITY IMPROVEMENT HAS HELD AT THE JANUARY LEVEL.

PRODUCTIVITY

LTV Aerospace and Defense
Vought Aero Products Division

## DIVISIONAL BUDGETS

FORECAST, $ MILLIONS

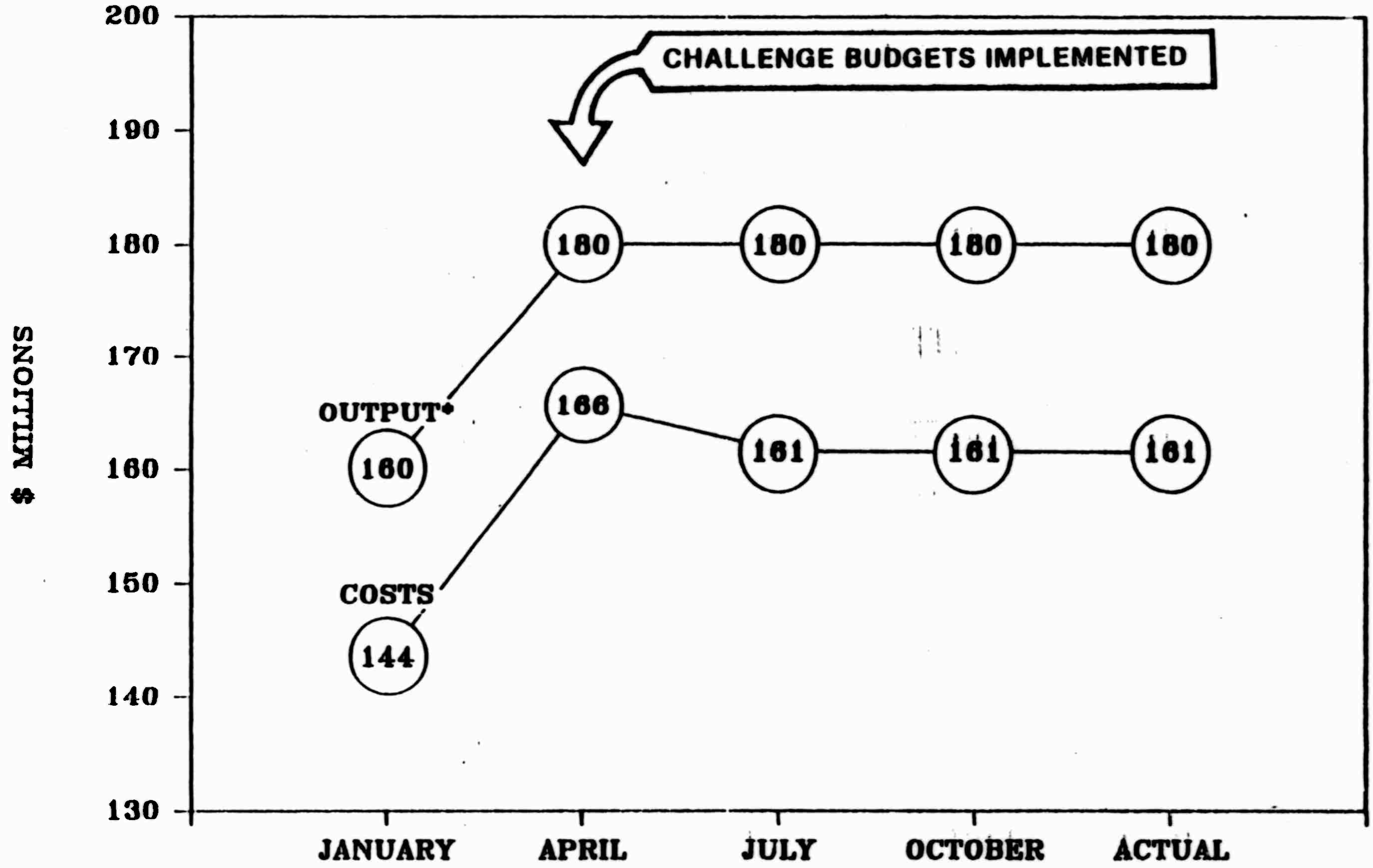
| | BASE YEAR | BASE YEAR + 1 | | | | |
|---|---|---|---|---|---|---|
| | ACTUAL | JANUARY | APRIL | JULY | OCTOBER | ACTUAL |
| **CURRENT DOLLARS** | | | | | | |
| SALES | 100 | 130 | 160 | 160 | 150 | 150 |
| INVENTORY | 80 | 110 | 100 | 100 | 110 | 110 |
| CHANGE IN INVENTORY | 20 | 30 | 20 | 20 | 30 | 30 |
| OUTPUT* | 120 | 160 | 180 | 180 | 180 | 180 |
| COSTS ( $\boxed{\text{BUDGET}}$ ) | 110 | $\boxed{144}$ | $\boxed{166}$ | $\boxed{161}$ | $\boxed{161}$ | 161 |
| **INFLATION** | | | | | | |
| OUTPUT | BASE | <---<---<--- | <---<---<--- | 3.0% | --->--->--- | --->---> |
| COSTS | BASE | <---<---<--- | <---<---<--- | 5.0% | --->--->--- | --->---> |
| **CONSTANT DOLLARS** | | | | | | |
| OUTPUT | 120 | 155 | 175 | 175 | 175 | 175 |
| COSTS | 110 | 137 | 158 | 154 | 154 | 154 |
| COSTS/OUTPUT | 91.7% | 88.0% | 90.3% | 88.0% | 88.0% | 88.0% |
| **PRODUCTIVITY IMPROVEMENT** | | | | | | |
| TARGET | BASE | >>>>>>>>>>>> | >>>>>>>>>>>> | >>>>>>>>>>>> | >>>>>>>>>>>> | >>>>>>> 3.0% |
| FORECAST | BASE | 4.0% | 1.5% | 4.0% | 4.0% | 4.0% |

DIVISIONAL BUDGETS

BASE YEAR + 1 -- ACTUAL VALUES

- VALUES ARE UNCHANGED FROM OCTOBER.
- ACTUAL PRODUCTIVITY IMPROVEMENT HAS EXCEEDED THE ANNUAL TARGET AND MEETS THE JANUARY FORECAST.

# DIVISIONAL BUDGETS




*OUTPUT = SALES + CHANGE IN INVENTORY

## DIVISIONAL BUDGETS

- IN JANUARY, FORECASTED ANNUAL OUTPUT AND COSTS ARE ESTABLISHED.
- THE APRIL FORECAST REVISED BOTH FACTORS UPWARD WITH COSTS INCREASING MORE THAN OUTPUT.
- CHALLENGE BUDGETS ARE IMPLEMENTED, AND THE RESULTING COST REDUCTION IS REFLECTED IN THE JULY REVISED FORECAST.
- THE FAVORABLE COST TO OUTPUT RATIO ESTABLISHED IN JULY IS MAINTAINED BY THE OCTOBER FORECAST AND AT YEARS'S END WHEN ACTUAL VALUES ARE KNOWN.

## DEPARTMENTAL BUDGETS

- EVERY FUNCTION DOES NOT NECESSARILY SUPPORT EVERY PROGRAM.
- RELATED OUTPUT FOR A FUNCTION IS THE PORTION OF DIVISION OUTPUT THAT THE FUNCTION DOES SUPPORT.

## DEPARTMENTAL BUDGETS

| | BASE YEAR | BASE YEAR + 1: CASE 1 | BASE YEAR + 1: CASE 2 |
|---|---|---|---|
| **OUTPUT** | | | |
| PROGRAM A | 20 | 80 | 80 |
| PROGRAM B | 100 | 100 | 100 |
| | 120 | 180 | 180 |
| **RELATED OUTPUT** | | | |
| MANUFACTURING A | 20 | 80 | 80 |
| MANUFACTURING B | 100 | 100 | 100 |
| MATERIALS A+B | 120 | 180 | 180 |
| GEN. & ADMIN. A+B | 120 | 180 | 180 |
| **BUDGET** | | | |
| MANUFACTURING A | 10 | 40 | 39 |
| MANUFACTURING B | 50 | 50 | 49 |
| MATERIALS A+B | 30 | 45 | 44 |
| GEN. & ADMIN. A+B | 20 | 30 | 29 |
| | 110 | 165 | 161 |
| **PRODUCTIVITY IMPROVEMENT** | | 0.0% | 4.0% |
| **INFLATION** | | | |
| OUTPUT | | 0.0% | 3.0% |
| COSTS | | 0.0% | 5.0% |

## DEPARTMENTAL BUDGETS

BASE YEAR

- PROGRAM A AND PROGRAM B REPRESENT THE DIVISION'S TOTAL OUTPUT.
- MANUFACTURING A SUPPORTS ONLY PROGRAM A.
- MANUFACTURING B SUPPORTS ONLY PROGRAM B.
- MATERIALS AND GENERAL AND ADMINISTRATION SUPPORT FULLY BOTH PROGRAM A AND PROGRAM B.
- THE FUNCTIONAL BUDGETS REFLECT COSTS ASSOCIATED WITH EACH FUNCTIONS RELATED OUTPUT.

## DEPARTMENTAL BUDGETS

| | BASE YEAR | BASE YEAR + 1 CASE 1 | BASE YEAR + 1 CASE 2 |
|---|---|---|---|
| **OUTPUT** | | | |
| PROGRAM A | 20 | 80 | 80 |
| PROGRAM B | 100 | 100 | 100 |
| | 120 | 180 | 180 |
| **RELATED OUTPUT** | | | |
| MANUFACTURING A | 20 | 80 | 80 |
| MANUFACTURING B | 100 | 100 | 100 |
| MATERIALS A+B | 120 | 180 | 180 |
| GEN. & ADMIN. A+B | 120 | 180 | 180 |
| **BUDGET** | | | |
| MANUFACTURING A | 10 | 40 | 39 |
| MANUFACTURING B | 50 | 50 | 49 |
| MATERIALS A+B | 30 | 45 | 44 |
| GEN. & ADMIN. A+B | 20 | 30 | 29 |
| | 110 | 165 | 161 |
| **PRODUCTIVITY IMPROVEMENT** | | 0.0% | 4.0% |
| **INFLATION** | | | |
| OUTPUT | | 0.0% | 3.0% |
| COSTS | | 0.0% | 5.0% |

## DEPARTMENTAL BUDGETS

BASE YEAR + 1 -- CASE 1

- IN CASE 1, THERE IS NO INFLATION AND NO PRODUCTIVITY IMPROVEMENT.
- PROGRAM A OUTPUT HAS INCREASED FOURFOLD, AND MANUFACTURING A RELATED OUTPUT AND BUDGET HAVE INCREASED FOURFOLD.
- PROGRAM B OUTPUT IS UNCHANGED, AND MANUFACTURING B RELATED OUTPUT AND BUDGET ARE UNCHANGED.
- TOTAL OUTPUT (PROGRAM A + PROGRAM B) HAS INCREASED 50%. MATERIALS AND GENERAL AND ADMINISTRATION, WHICH SUPPORT BOTH PROGRAM A AND AND PROGRAM B, SHOW A 50% INCREASE IN RELATED OUTPUT AND BUDGETS.

## DEPARTMENTAL BUDGETS

| | BASE YEAR | BASE YEAR + 1 CASE 1 | BASE YEAR + 1 CASE 2 |
|---|---|---|---|
| **OUTPUT** | | | |
| PROGRAM A | 20 | 80 | 80 |
| PROGRAM B | 100 | 100 | 100 |
| | 120 | 180 | 180 |
| **RELATED OUTPUT** | | | |
| MANUFACTURING A | 20 | 80 | 80 |
| MANUFACTURING B | 100 | 100 | 100 |
| MATERIALS A+B | 120 | 180 | 180 |
| GEN. & ADMIN. A+B | 120 | 180 | 180 |
| **BUDGET** | | | |
| MANUFACTURING A | 10 | 40 | 39 |
| MANUFACTURING B | 50 | 50 | 49 |
| MATERIALS A+B | 30 | 45 | 44 |
| GEN. & ADMIN. A+B | 20 | 30 | 29 |
| | 110 | 165 | 161 |
| **PRODUCTIVITY IMPROVEMENT** | | 0.0% | 4.0% |
| **INFLATION** | | | |
| OUTPUT | | 0.0% | 3.0% |
| COSTS | | 0.0% | 5.0% |

## DEPARTMENTAL BUDGETS

DASE YEAR + 1 -- CASE 2

- CASE 2 IS SIMILAR TO CASE 1 EXCEPT THAT INFLATION AND PRODUCTIVITY IMPROVEMENT ARE INTRODUCED.
- TO ACHIEVE THE DESIRED PRODUCTIVITY IMPROVEMENT, BUDGETS ARE REDUCED PROPORTIONATELY.

## SOURCING ADJUSTMENT

- CHANGES IN PRODUCT MIX FROM YEAR TO YEAR CAN CAUSE SIGNIFICANT SHIFTS IN THE "MAKE VERSUS BUY" PROPORTION OF BUDGETS.
- DIRECT MATERIALS IS THE "BUY" PROPORTION OF BUDGETS.
- ALL COSTS EXCEPT DIRECT MATERIALS ARE INCLUDED IN THE "MAKE" PROPORTION OF BUDGETS.
- IF THE FORECASTED MAKE/BUY RATIOS DO NOT MATCH THE VALUES IN THE BASE YEAR, THEN ADJUSTMENTS MUST BE MADE IN THE CHALLENGE BUDGETS TO ACCOUNT FOR THE SHIFT IN MAKE AND BUY.

## SOURCING ADJUSTMENT

| | BASE YEAR | | | | BASE YEAR + 1 | |
|---|---|---|---|---|---|---|
| | ACTUAL | | ADJUSTED | | | |
| | $ MILLION | SOURCING % | $ MILLION | SOURCING % | SOURCING % | BUDGET $ MILLION |
| OUTPUT | 120 | - | 120 | - | - | 180 |
| BUDGET | | | | | | |
| MANUFACTURING | 60 | 73% | 52 | 63% | 63% | 76 |
| GEN. & ADMIN. | 20 | | 17 | | | 25 |
| | 80 | | 69 | | | 101 |
| MATERIALS | 30 | 27% | 41 | 37% | 37% | 60 |
| | 110 | 100% | 110 | 100% | | 161 |
| PRODUCTIVITY IMPROVEMENT | | | | | | 4.0% |
| INFLATION | | | | | | |
| OUTPUT | | | | | | 3.0% |
| COSTS | | | | | | 5.0% |

## SOURCING ADJUSTMENT

BASE YEAR -- ACTUAL VALUES

- MATERIALS (BUY) REPRESENTS 27% OF TOTAL COSTS.
- ALL OTHER COSTS (MAKE) REPRESENTS 73% OF TOTAL COSTS.

## SOURCING ADJUSTMENT

| | BASE YEAR | | | | BASE YEAR + 1 | |
|---|---|---|---|---|---|---|
| | ACTUAL | | ADJUSTED | | | |
| | $ MILLION | SOURCING % | $ MILLION | SOURCING % | SOURCING % | BUDGET $ MILLION |
| OUTPUT | 120 | - | 120 | - | - | 180 |
| BUDGET | | | | | | |
| MANUFACTURING | 60 | 73% | 52 | 63% | 63% | 76 |
| GEN. & ADMIN. | 20 | | 17 | | | 25 |
| | 80 | | 69 | | | 101 |
| MATERIALS | 30 | 27% | 41 | 37% | 37% | 60 |
| | 110 | 100% | 110 | 100% | | 161 |
| PRODUCTIVITY IMPROVEMENT | | | | | | 4.0% |
| INFLATION | | | | | | |
| OUTPUT | | | | | | 3.0% |
| COSTS | | | | | | 5.0% |

## SOURCING ADJUSTMENT

BASE YEAR + 1 -- SOURCING PERCENT

- MATERIALS (BUY) IS FORECASTED TO BE 37% OF TOTAL COSTS.
- ALL OTHER COSTS (MAKE) ARE FORECASTED TO BE 63% OF TOTAL COSTS.

## SOURCING ADJUSTMENT

| | BASE YEAR | | | | BASE YEAR + 1 | |
|---|---|---|---|---|---|---|
| | ACTUAL | | ADJUSTED | | | |
| | $ MILLION | SOURCING % | $ MILLION | SOURCING % | SOURCING % | BUDGET $ MILLION |
| OUTPUT | 120 | - | 120 | - | - | 180 |
| BUDGET | | | | | | |
| MANUFACTURING | 60 | 73% | 52 | 63% | 63% | 76 |
| GEN. & ADMIN. | 20 | | 17 | | | 25 |
| | 80 | | 69 | | | 101 |
| MATERIALS | 30 | 27% | 41 | 37% | 37% | 60 |
| | 110 | 100% | 110 | 100% | | 161 |
| PRODUCTIVITY IMPROVEMENT | | | | | | 4.0% |
| INFLATION | | | | | | |
| OUTPUT | | | | | | 3.0% |
| COSTS | | | | | | 5.0% |

## SOURCING ADJUSTMENT

BASE YEAR -- ADJUSTED

- COSTS ARE PROPORTIONATELY REVISED TO REFLECT THE SOURCING PERCENTAGES IN BASE YEAR + 1.

## SOURCING ADJUSTMENT

| | BASE YEAR | | | | BASE YEAR + 1 | |
|---|---|---|---|---|---|---|
| | ACTUAL | | ADJUSTED | | | |
| | $ MILLION | SOURCING % | $ MILLION | SOURCING % | SOURCING % | BUDGET $ MILLION |
| OUTPUT | 120 | - | 120 | - | - | 180 |
| BUDGET | | | | | | |
| MANUFACTURING | 60 | 73% | 52 | 63% | 63% | 76 |
| GEN. & ADMIN. | 20 | | 17 | | | 25 |
| | 80 | | 69 | | | 101 |
| MATERIALS | 30 | 27% | 41 | 37% | 37% | 60 |
| | 110 | 100% | 110 | 100% | | 161 |
| PRODUCTIVITY IMPROVEMENT | | | | | | 4.0% |
| INFLATION | | | | | | |
| OUTPUT | | | | | | 3.0% |
| COSTS | | | | | | 5.0% |

SOURCING ADJUSTMENT

BASE YEAR + 1 -- BUDGET

- BUDGETS ARE FORECAST THAT REFLECT THE ADJUSTED BASE YEAR (SOURCING ADJUSTMENT), THE FORECASTED OUTPUT, TARGETED PRODUCTIVITY IMPROVEMENT, AND FORECASTED INFLATION.

PRODUCTIVITY

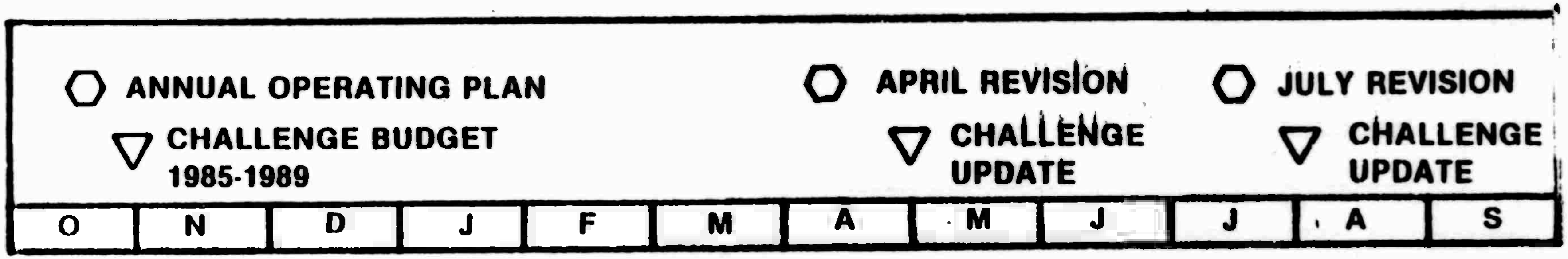
LTV Aerospace and Defense
Vought Aero Products Division

# BUDGETS FOLLOW ORGANIZATIONAL LINES

RESPONSIBLE FUNCTIONS

- MANUFACTURING OPERATIONS
- MATERIALS
- QUALITY ASSURANCE
- ENGINEERING
- INDUSTRIAL MODERNIZATION
- FACILITIES
- VOUGHT OVERHAUL AND MODERNIZATION CENTER
- LOGISTICS
- HUMAN RESOURCES
- INFORMATION SERVICES
- FINANCE
- PROGRAM MANAGEMENT

# TIMING


ANNUAL OPERATING PLAN
CHALLENGE BUDGET
1985-1989
APRIL REVISION
CHALLENGE
UPDATE
JULY REVISION
CHALLENGE
UPDATE
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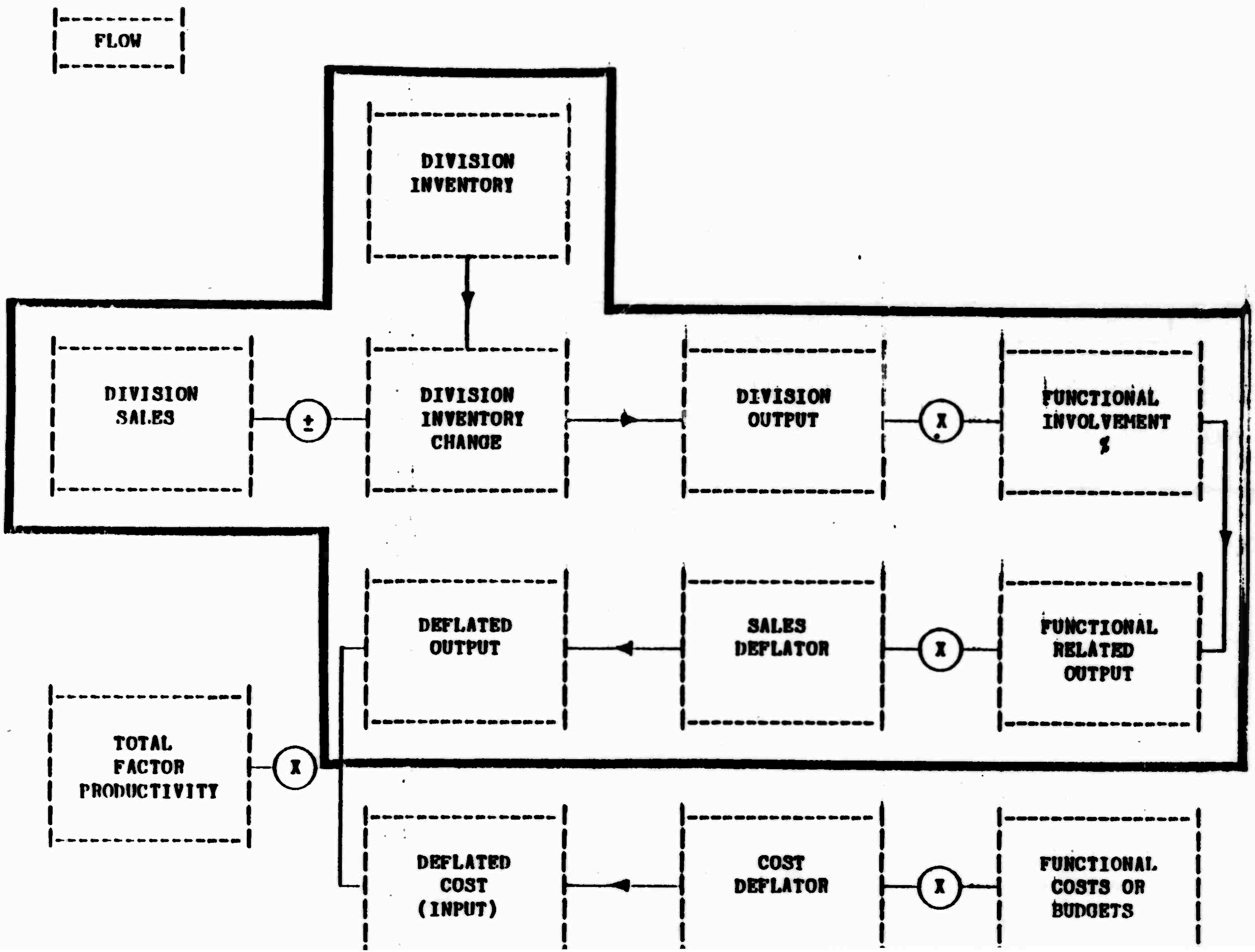
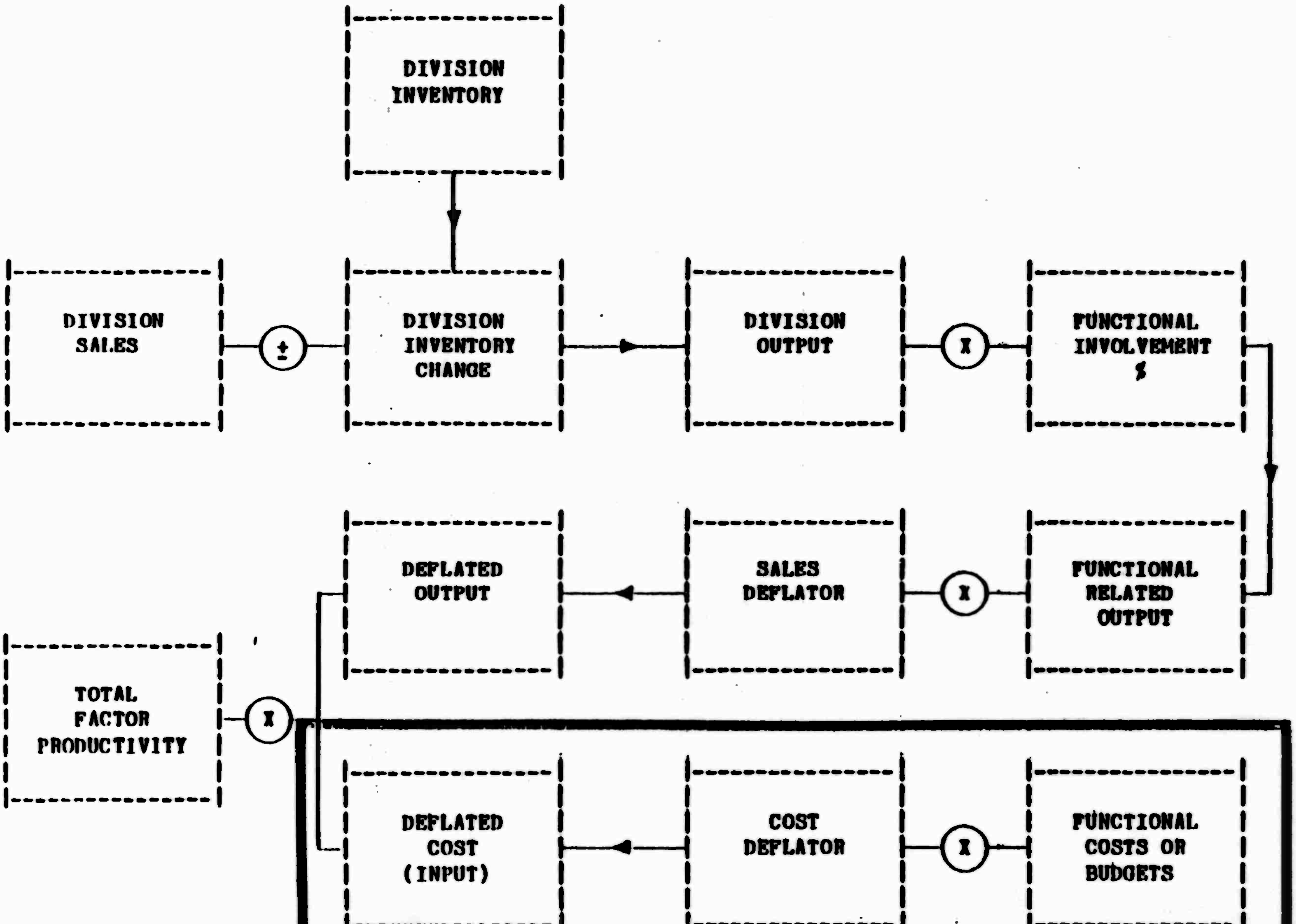

FLOW
DIVISION INVENTORY
DIVISION SALES
±
DIVISION INVENTORY CHANGE
DIVISION OUTPUT
X
FUNCTIONAL INVOLVEMENT %
DEFLATED OUTPUT
SALES DEFLATOR
X
FUNCTIONAL RELATED OUTPUT
TOTAL FACTOR PRODUCTIVITY
X
DEFLATED COST (INPUT)
COST DEFLATOR
X
FUNCTIONAL COSTS OR BUDGETS

## FLOW

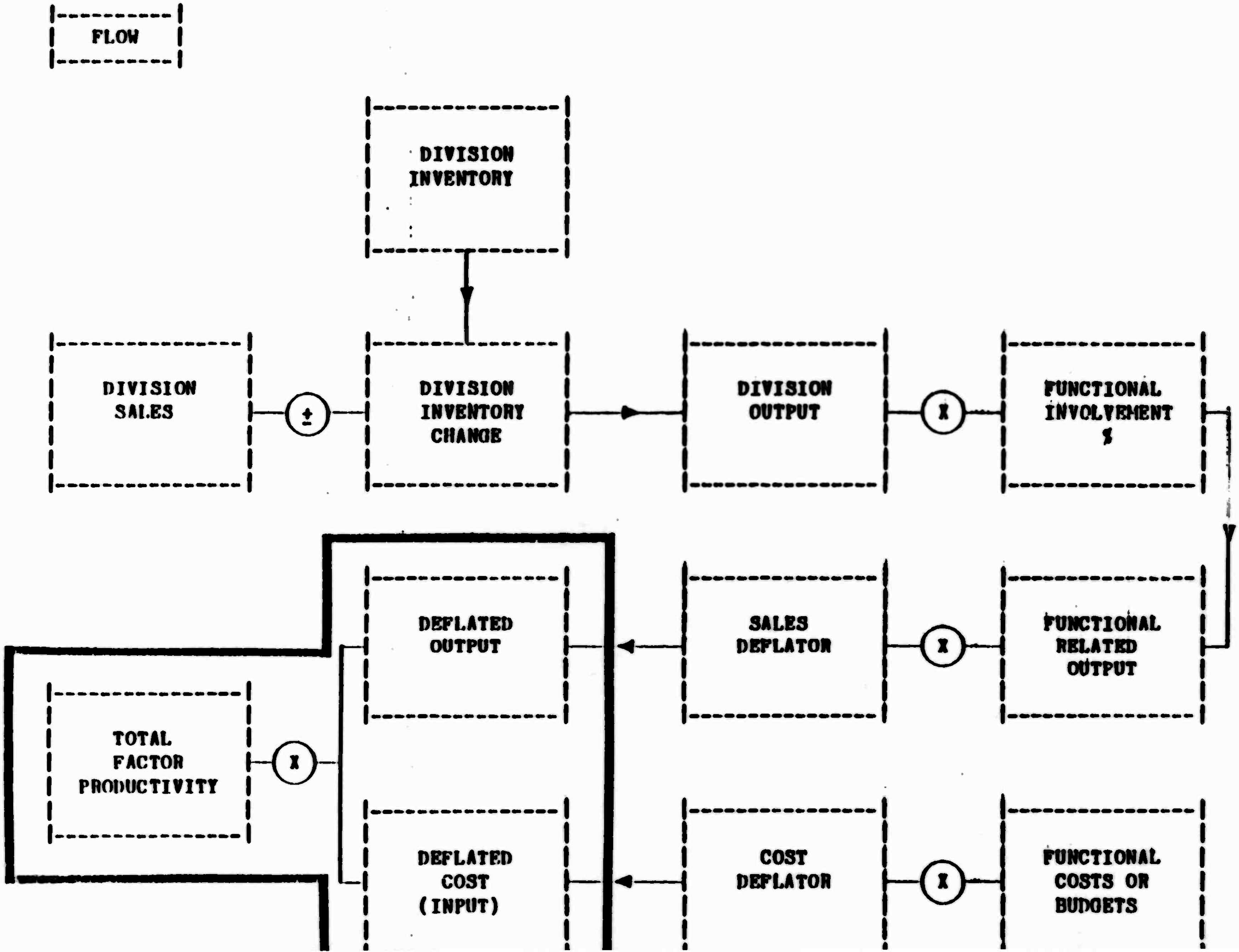
- DIVISION ANNUAL SALES AND YEAR-END INVENTORIES ARE INPUT INTO THE MODEL.
- MODEL CALCULATES CHANGE IN INVENTORY AND OUTPUT (OUTPUT = SALES + CHANGE IN INVENTORY).
- FUNCTIONAL INVOLVEMENT IN OUTPUT IS ENTERED INTO THE MODEL.
- THE MODEL CALCULATES THE FUNCTIONAL RELATED OUTPUT (FUNCTIONAL RELATED OUTPUT = DIVISIONAL OUTPUT x FUNCTIONAL INVOLVEMENT).
- SALES DEFLATOR IS ENTERED INTO THE MODEL.
- THE MODEL CALCULATES DEFLATED OUTPUT.

FLOW


DIVISION INVENTORY
DIVISION SALES
±
DIVISION INVENTORY CHANGE
DIVISION OUTPUT
X
FUNCTIONAL INVOLVEMENT $
FUNCTIONAL RELATED OUTPUT
X
SALES DEFLATOR
DEFLATED OUTPUT
TOTAL FACTOR PRODUCTIVITY
X
DEFLATED COST (INPUT)
COST DEFLATOR
X
FUNCTIONAL COSTS OR BUDGETS

## FLOW

- FUNCTIONAL COSTS OR FORECASTED BUDGETS ARE ENTERED INTO THE MODEL.
- COST DEFLATORS ARE ENTERED INTO THE MODEL.
- THE MODEL CALCULATES DEFLATED COST (INPUT).


FLOW
DIVISION INVENTORY
DIVISION SALES
±
DIVISION INVENTORY CHANGE
DIVISION OUTPUT
X
FUNCTIONAL INVOLVEMENT %
DEFLATED OUTPUT
SALES DEFLATOR
X
FUNCTIONAL RELATED OUTPUT
TOTAL FACTOR PRODUCTIVITY
X
DEFLATED COST (INPUT)
COST DEFLATOR
X
FUNCTIONAL COSTS OR BUDGETS

| FLOW |

- USING DEFLATED OUTPUT AND DEFLATED COST, THE MODEL CALCULATES THE COST TO OUTPUT RATIOS AND YEAR OVER YEAR TOTAL FACTOR PRODUCTIVITY.

CHALLENGE BUDGETS

| SEQUENCE OF CALCULATION | ITEM | BASE YEAR | BASE YEAR + 1 | LOGIC (REFER TO BASE YEAR + 1 COLUMN) |
|---|---|---|---|---|
| | **OUTPUT** | | | |
| 1 | CURRENT YEAR VALUE | 111.00 | 222.00 | FINANCE FORECAST |
| 2 | PRICE INFLATION % | BASE | 8.00% | DATA RESOURCES, INC. FORECAST |
| 3 | INFLATION INDEX | 100.00% | 108.00% | 108.00% = 100% + (8% OF 100%) |
| 4 | BASE YEAR VALUE | 111.00 | 205.56 | 205.56 = 222.00 ÷ 108.00% |
| | **INPUT (TOTAL RESOURCES)** | | | |
| 10 | CURRENT YEAR VALUE | 100.00 | 195.56 | 195.56 = (110.00% OF 177.78) |
| 5 | COST INFLATION % | BASE | 10.00% | DATA RESOURCES, INC. FORECAST |
| 6 | INFLATION INDEX | 100.00% | 110.00% | 110.00% = 100% + (10% OF 100%) |
| 9 | BASE YEAR VALUE | 100.00 | 177.78 | 177.78 = (86.49% OF 205.56) |
| 8 | % OF SALES - BYV | 90.09% | 86.49% | 86.49% = 90.09% - (4% OF 90.09%) |
| | **PRODUCTIVITY IMPROVEMENT** | | | |
| 7 | TARGET % | BASE | 4.00% | ANNUAL PRODUCTIVITY GOAL |

## CHALLENGE BUDGETS

- THE TOTAL FACTOR PRODUCTIVITY MODEL CALCULATES CHALLENGE BUDGETS USING BASE YEAR FINANCIAL DATA, PRODUCTIVITY IMPROVEMENT TARGET, AND FORECASTS FOR OUTPUT AND INFLATION.
- FOR SIMPLICITY, THE EXAMPLE SHOWS CHALLENGE BUDGET CALCULATIONS FOR TOTAL COSTS ONLY. HOWEVER, THE TOTAL FACTOR MODEL CALCULATES CHALLENGE BUDGETS FOR CATEGORIES AND SUB-CATEGORIES OF LABOR, MATERIALS, ENERGY, AND CAPITAL.

SALES - LTV VOUGHT

| CONTRACT | $(000,000) | | | |
|---|---|---|---|---|
| | 1983 BASE | 1984 APRIL | 1985 | 1986 |
| AERO PRODUCTS DIVISION | | | | |
| SUBCONTRACTS: | | | | |
| 747 | 11.15 | 11.54 | 12.31 | 13.63 |
| 757 | 12.40 | 14.51 | 14.35 | 26.29 |
| 767 | 9.48 | 6.75 | 6.88 | 10.92 |
| DC-10 | 4.41 | 5.11 | 8.84 | 8.70 |
| CL-601 | 12.52 | 7.41 | 6.47 | 6.26 |
| B-1B | 41.42 | 37.67 | 99.67 | 139.04 |
| OTHER | 10.57 | 7.84 | 6.76 | 6.66 |
| AIRCRAFT/AFTERMARKET: | | | | |
| A-7K | 18.29 | 3.20 | 0.42 | 0.00 |
| A-7 D/E/H | 5.50 | 5.30 | 0.67 | 0.18 |
| KITS & OTHER A-7 | 21.76 | 15.09 | 34.54 | 22.38 |
| PORTUGUESE | 3.86 | 9.13 | 34.17 | 4.44 |
| PHILIPPINES | 0.16 | 0.82 | 0.63 | 0.44 |
| SDLM | 1.05 | 1.76 | 1.08 | 1.24 |
| ASO SPARES | 12.09 | 10.88 | 12.77 | 11.50 |
| OTHER | 19.70 | 37.21 | 83.44 | 106.58 |
| OTHER | 3.28 | 5.38 | 8.93 | 9.95 |
| TOTAL AERO PRODUCTS | 187.63 | 179.60 | 331.93 | 368.24 |
| TOTAL MISSILES & ADV. PROGRAMS | 127.45 | 166.06 | 174.95 | 202.33 |
| TOTAL LTV VOUGHT | 315.08 | 345.66 | 506.88 | 570.57 |

INVENTORY - LTV VOUGHT

| CONTRACT | $(000,000) | | | | |
|---|---|---|---|---|---|
| | 1982 | 1983 BASE | 1984 APRIL | 1985 | 1986 |
| AERO PRODUCTS DIVISION | | | | | |
| SUBCONTRACTS: | | | | | |
| 747 | 10.03 | 9.57 | 14.94 | 12.83 | 11.63 |
| 757 | 17.42 | 19.34 | 17.86 | 20.08 | 16.54 |
| 767 | 7.13 | 4.67 | 4.17 | 3.76 | 4.32 |
| DC-10 | 3.03 | 2.49 | 4.21 | 5.01 | 4.54 |
| CL-601 | 8.04 | 4.20 | 3.08 | 2.56 | 0.80 |
| B-1B | 19.90 | 40.98 | 103.43 | 111.81 | 105.48 |
| OTHER | 2.40 | -0.29 | 2.30 | 1.46 | 1.09 |
| AIRCRAFT/AFTERMARKET: | | | | | |
| A-7K | 7.04 | 0.16 | 0.00 | .00 | 0.00 |
| A-7 D/E/H | 1.65 | 0.71 | 0.41 | 0.16 | 0.05 |
| KITS & OTHER A-7 | 5.89 | 7.46 | 9.52 | 14.97 | 21.11 |
| PORTUGUESE | 1.32 | 8.32 | 17.20 | 1.13 | -0.51 |
| PHILIPPINES | -0.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| SDLM | 0.04 | 0.46 | 0.35 | -0.49 | -0.90 |
| ASO SPARES | 0.16 | 0.63 | 0.63 | 2.33 | 3.46 |
| OTHER | -0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| OTHER | 0.19 | -1.82 | -2.41 | 0.02 | -0.36 |
| TOTAL AERO PRODUCTS | 84.18 | 96.88 | 175.70 | 175.63 | 167.27 |
| TOTAL MISSILES & ADV. PROGRAMS | 4.18 | 11.40 | 15.05 | 15.67 | 21.67 |
| TOTAL LTV VOUGHT | 88.36 | 108.28 | 190.75 | 191.30 | 188.94 |

## CHANGE IN INVENTORY - LTV VOUGHT

| CONTRACT | | $(000,000) | | | |
|---|---|---|---|---|---|
| | | 1983 BASE | 1984 APRIL | 1985 | 1986 |
| AERO PRODUCTS DIVISION | | | | | |
| SUBCONTRACTS: | | | | | |
| 747 | | -0.46 | 5.37 | -2.11 | -1.20 |
| 757 | | 1.92 | -1.47 | 2.21 | -3.53 |
| 767 | | -2.46 | -0.49 | -0.42 | 0.56 |
| DC-10 | | -0.54 | 1.72 | 0.80 | -0.47 |
| CL-601 | | -3.85 | -1.11 | -0.52 | -1.76 |
| B-1B | | 21.09 | 62.45 | 8.38 | -6.33 |
| OTHER | | -2.69 | 2.59 | -0.84 | -0.37 |
| AIRCRAFT/AFTERMARKET: | | | | | |
| A-7K | | -6.88 | -0.16 | .00 | .00 |
| A-7 D/E/H | | -0.94 | -0.30 | -0.25 | -0.11 |
| KITS & OTHER A-7 | | 1.58 | 2.05 | 5.45 | 6.14 |
| PORTUGUESE | | 7.00 | 8.88 | -16.07 | -1.63 |
| PHILIPPINES | | 0.03 | 0.00 | 0.00 | 0.00 |
| SDLM | | 0.42 | -0.11 | -0.84 | -0.40 |
| ASO SPARES | | 0.47 | .00 | 1.70 | 1.13 |
| OTHER | | 0.01 | 0.00 | 0.00 | 0.00 |
| OTHER | | -2.00 | -0.59 | 2.43 | -0.38 |
| TOTAL AERO PRODUCTS | | 12.70 | 78.82 | -0.06 | -8.36 |
| TOTAL MISSILES & ADV. PROGRAMS | | 7.23 | 3.65 | 0.62 | 6.00 |
| TOTAL LTV VOUGHT | | 19.92 | 82.46 | 0.56 | -2.37 |
| PROFIT ADJUSTMENT ON INVENTORY | 7.00% | 1.39 | 5.77 | 0.04 | -0.17 |
| ADJUSTED TOTAL | | 21.32 | 88.24 | 0.59 | -2.53 |

SALES + CHANGE IN INVENTORY - LTV VOUGHT

| CONTRACT | | $(000,000) 1983 BASE | 1984 APRIL | 1985 | 1986 |
|---|---|---|---|---|---|
| AERO PRODUCTS DIVISION | | | | | |
| SUBCONTRACTS: | | | | | |
| 747 | | 10.70 | 16.91 | 10.20 | 12.43 |
| 757 | | 14.32 | 13.03 | 16.57 | 22.76 |
| 767 | | 7.02 | 6.25 | 6.47 | 11.49 |
| DC-10 | | 3.86 | 6.83 | 9.64 | 8.23 |
| CL-601 | | 8.67 | 6.30 | 5.94 | 4.50 |
| B-1B | | 62.50 | 100.12 | 108.05 | 132.72 |
| OTHER | | 7.88 | 10.43 | 5.92 | 6.29 |
| AIRCRAFT/AFTERMARKET: | | | | | |
| A-7K | | 11.42 | 3.03 | 0.42 | .00 |
| A-7 D/E/H | | 4.55 | 5.01 | 0.42 | 0.07 |
| KITS & OTHER A-7 | | 23.34 | 17.15 | 40.00 | 28.52 |
| PORTUGUESE | | 10.86 | 18.00 | 18.10 | 2.81 |
| PHILIPPINES | | 0.19 | 0.82 | 0.63 | 0.44 |
| SDLM | | 1.48 | 1.65 | 0.24 | 0.84 |
| ASO SPARES | | 12.56 | 10.88 | 14.47 | 12.64 |
| OTHER | | 19.70 | 37.21 | 83.44 | 106.58 |
| OTHER | | 1.27 | 4.79 | 11.36 | 9.56 |
| TOTAL AERO PRODUCTS | | 200.32 | 258.41 | 331.87 | 359.88 |
| TOTAL MISSILES & ADV. PROGRAMS | | 134.68 | 169.71 | 175.57 | 208.33 |
| TOTAL LTV VOUGHT | | 335.00 | 428.12 | 507.44 | 568.20 |
| PROFIT ADJUSTMENT PERCENT | 7.00% | 1.39 | 5.77 | 0.04 | -0.17 |
| ADJUSTED TOTAL | | 336.40 | 433.89 | 507.48 | 568.04 |

PERCENT INVOLVEMENT IN OUTPUT - AERO PRODUCTS DIVISION

| CONTRACT | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|
| AERO PRODUCTS DIVISION | | | | |
| SUBCONTRACTS: | | | | |
| 747 | 100.00 | 100.00 | 100.00 | 100.00 |
| 757 | 100.00 | 100.00 | 100.00 | 100.00 |
| 767 | 100.00 | 100.00 | 100.00 | 100.00 |
| DC-10 | 100.00 | 100.00 | 100.00 | 100.00 |
| CL-601 | 100.00 | 100.00 | 100.00 | 100.00 |
| B-1B | 100.00 | 100.00 | 100.00 | 100.00 |
| OTHER | 100.00 | 100.00 | 100.00 | 100.00 |
| AIRCRAFT/AFTERMARKET: | | | | |
| A-7K | 100.00 | 100.00 | 100.00 | 100.00 |
| A-7 D/E/H | 100.00 | 100.00 | 100.00 | 100.00 |
| KITS & OTHER A-7 | 100.00 | 100.00 | 100.00 | 100.00 |
| PORTUGUESE | 100.00 | 100.00 | 100.00 | 100.00 |
| PHILIPPINES | 100.00 | 100.00 | 100.00 | 100.00 |
| SDLM | 100.00 | 100.00 | 100.00 | 100.00 |
| ASO SPARES | 100.00 | 100.00 | 100.00 | 100.00 |
| OTHER | 100.00 | 100.00 | 100.00 | 100.00 |
| OTHER | 100.00 | 100.00 | 100.00 | 100.00 |
| MISSILES & ADVANCED PROGRAMS | 100.00 | 0.00 | 0.00 | 0.00 |

SALES + CHANGE IN INVENTORY - AERO PRODUCTS DIVISION

| CONTRACT | | $(000,000) 1983 BASE | 1984 APRIL | 1985 | 1986 |
|---|---|---|---|---|---|
| AERO PRODUCTS DIVISION | | | | | |
| SUBCONTRACTS: | | | | | |
| 747 | | 10.70 | 16.91 | 10.20 | 12.43 |
| 757 | | 14.32 | 13.03 | 16.57 | 22.76 |
| 767 | | 7.02 | 6.25 | 6.47 | 11.49 |
| DC-10 | | 3.86 | 6.83 | 9.64 | 8.23 |
| CL-601 | | 8.67 | 6.30 | 5.94 | 4.50 |
| B-1B | | 62.50 | 100.12 | 108.05 | 132.72 |
| OTHER | | 7.88 | 10.43 | 5.92 | 6.29 |
| AIRCRAFT/AFTERMARKET: | | | | | |
| A-7K | | 11.42 | 3.03 | 0.42 | .00 |
| A-7 D/E/H | | 4.55 | 5.01 | 0.42 | 0.07 |
| KITS & OTHER A-7 | | 23.34 | 17.15 | 40.00 | 28.52 |
| PORTUGUESE | | 10.86 | 18.00 | 18.10 | 2.81 |
| PHILIPPINES | | 0.19 | 0.82 | 0.63 | 0.44 |
| SDLM | | 1.48 | 1.65 | 0.24 | 0.84 |
| ASO SPARES | | 12.56 | 10.88 | 14.47 | 12.64 |
| OTHER | | 19.70 | 37.21 | 83.44 | 106.58 |
| OTHER | | 1.27 | 4.79 | 11.36 | 9.56 |
| TOTAL AERO PRODUCTS | | 200.32 | 258.41 | 331.87 | 359.88 |
| TOTAL MISSILES & ADV. PROGRAMS | | 75.02 | 0.00 | 0.00 | 0.00 |
| TOTAL LTV VOUGHT | | 275.35 | 258.41 | 331.87 | 359.88 |
| PROFIT ADJUSTMENT PERCENT | 7.00% | 1.01 | 5.52 | .00 | -0.59 |
| ADJUSTED TOTAL | | 276.36 | 263.93 | 331.86 | 359.29 |

## 1984 ANNUAL OPERATING PLAN, APRIL REVISION - AERO PRODUCTS DIVISION

| ITEM | BASELINE $(000) | AOP BUDGETS $(000) | | |
|---|---|---|---|---|
| | 1983 | 1984 | 1985 | 1986 |
| EQUIV.DIV.IMPRVMNT | BASE | 1.66 | 3.25 | 3.90 |
| BUY - PERCENT OF COSTS | 22.54 | 27.14 | 30.10 | 28.38 |
| MAKE - PERCENT OF COSTS | 77.46 | 72.86 | 69.90 | 71.62 |
| SALES+CHANGE IN INVENTORY | 276358 | 263929 | 331859 | 359291 |
| LABOR | | | | |
| DIRECT - SALARY & WAGES | 57797 | 51596 | 61134 | 65726 |
| OTHER DIRECT CHARGES | 15836 | 10693 | 8059 | 9973 |
| INDIRECT - SALARY & WAGES | 36933 | 32375 | 38662 | 40662 |
| FRINGES | 36293 | 32786 | 44667 | 48308 |
| TOTAL LABOR | 146860 | 127449 | 152522 | 164668 |
| MATERIAL | | | | |
| DIRECT | 55158 | 63417 | 88908 | 88325 |
| ODC | 10557 | 7128 | 5373 | 6648 |
| INDIRECT | | | | |
| SUPPLIES & EXPENSES | 10740 | 10780 | 11828 | 11318 |
| CREDITS | -699 | -910 | -631 | -862 |
| NON DEPARTMENT | 0 | 0 | 0 | 0 |
| OTHER | 0 | 0 | 0 | 0 |
| TOTAL MATERIAL | 75756 | 80416 | 105477 | 105430 |
| ENERGY | 4130 | 4090 | 4787 | 5575 |
| CAPITAL | | | | |
| LEASE COSTS | 1716 | 1855 | 3209 | 3494 |
| INSURANCE,RENT,TAXES | 7582 | 5950 | 6631 | 6871 |
| DEPRECIATION & AMORT. | 2198 | 1858 | 2084 | 2575 |
| <<< TOTAL >>> | 238242 | 221619 | 274711 | 288613 |
| MEMO: ALLOCATIONS | | | | |
| DIVISIONAL & CORPORATE | 6496 | 7172 | 8291 | 7880 |
| TOTAL+ALLOCATIONS | 244738 | 228790 | 283002 | 296492 |

## NOMINAL CHALLENGE BUDGETS, APRIL REVISION - AERO PRODUCTS DIVISION

| ITEM | BASELINE $(000) | AOP BUDGETS $(000) | | |
|---|---|---|---|---|
| | 1983 | 1984 | 1985 | 1986 |
| EQUIV.DIV.IMPRVMNT | BASE | 3.00 | 4.00 | 4.00 |
| BUY - PERCENT OF COSTS | 22.54 | 27.14 | 30.10 | 28.38 |
| MAKE - PERCENT OF COSTS | 77.46 | 72.86 | 69.90 | 71.62 |
| SALES+CHANGE IN INVENTORY | 276358 | 263929 | 331859 | 359291 |
| LABOR | | | | |
| DIRECT - SALARY & WAGES | 57797 | 49231 | 55968 | 58368 |
| OTHER DIRECT CHARGES | 15836 | 13489 | 15335 | 15993 |
| INDIRECT - SALARY & WAGES | 36933 | 31459 | 35765 | 37299 |
| FRINGES | 36293 | 30914 | 35145 | 36652 |
| TOTAL LABOR | 146860 | 125093 | 142213 | 148312 |
| MATERIAL | | | | |
| DIRECT | 55158 | 63245 | 89038 | 89572 |
| ODC | 10557 | 9182 | 10815 | 11750 |
| INDIRECT | | | | |
| SUPPLIES & EXPENSES | 10740 | 9341 | 11002 | 11954 |
| CREDITS | -699 | -802 | -1129 | -1136 |
| NON DEPARTMENT | 0 | 0 | 0 | 0 |
| OTHER | 0 | 0 | 0 | 0 |
| TOTAL MATERIAL | 75756 | 80966 | 109725 | 112141 |
| ENERGY | 4130 | 3585 | 4223 | 4510 |
| CAPITAL | | | | |
| LEASE COSTS | 1716 | 1458 | 1650 | 1706 |
| INSURANCE,RENT,TAXES | 7582 | 6440 | 7290 | 7534 |
| DEPRECIATION & AMORT. | 2198 | 1867 | 2113 | 2184 |
| <<< TOTAL >>> | 238242 | 219408 | 267216 | 276386 |
| MEMO: ALLOCATIONS | | | | |
| DIVISIONAL & CORPORATE | 6496 | 5699 | 6633 | 7036 |
| TOTAL+ALLOCATIONS | 244738 | 225107 | 273849 | 283422 |

PERCENT INVOLVEMENT IN OUTPUT - QUALITY ASSURANCE

| CONTRACT | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|
| AERO PRODUCTS DIVISION | | | | |
| SUBCONTRACTS: | | | | |
| 747 | 100.00 | 100.00 | 100.00 | 100.00 |
| 757 | 100.00 | 100.00 | 100.00 | 100.00 |
| 767 | 100.00 | 100.00 | 100.00 | 100.00 |
| DC-10 | 100.00 | 100.00 | 100.00 | 100.00 |
| CL-601 | 100.00 | 100.00 | 100.00 | 100.00 |
| B-1B | 100.00 | 100.00 | 100.00 | 100.00 |
| OTHER | 100.00 | 100.00 | 100.00 | 100.00 |
| AIRCRAFT/AFTERMARKET: | | | | |
| A-7K | 4.00 | 4.00 | 4.00 | 4.00 |
| A-7 D/E/H | 4.00 | 4.00 | 4.00 | 4.00 |
| KITS & OTHER A-7 | 90.00 | 90.00 | 90.00 | 90.00 |
| PORTUGUESE | 45.00 | 45.00 | 45.00 | 45.00 |
| PHILIPPINES | 45.00 | 45.00 | 45.00 | 45.00 |
| SDLM | 10.00 | 10.00 | 10.00 | 10.00 |
| ASO SPARES | 100.00 | 100.00 | 100.00 | 100.00 |
| OTHER | 10.00 | 30.00 | 40.00 | 50.00 |
| OTHER | 100.00 | 100.00 | 100.00 | 100.00 |
| MISSILES & ADVANCED PROGRAMS | 5.00 | 0.00 | 0.00 | 0.00 |

SALES + CHANGE IN INVENTORY - QUALITY ASSURANCE

| CONTRACT | $(000,000) 1983 BASE | 1984 APRIL | 1985 | 1986 |
|---|---|---|---|---|
| AERO PRODUCTS DIVISION | | | | |
| SUBCONTRACTS: | | | | |
| 747 | 10.70 | 16.91 | 10.20 | 12.43 |
| 757 | 14.32 | 13.03 | 16.57 | 22.76 |
| 767 | 7.02 | 6.25 | 6.47 | 11.49 |
| DC-10 | 3.86 | 6.83 | 9.64 | 8.23 |
| CL-601 | 8.67 | 6.30 | 5.94 | 4.50 |
| B-1B | 62.50 | 100.12 | 108.05 | 132.72 |
| OTHER | 7.88 | 10.43 | 5.92 | 6.29 |
| AIRCRAFT/AFTERMARKET: | | | | |
| A-7K | 0.46 | 0.12 | 0.02 | .00 |
| A-7 D/E/H | 0.18 | 0.20 | 0.02 | .00 |
| KITS & OTHER A-7 | 21.00 | 15.43 | 36.00 | 25.67 |
| PORTUGUESE | 4.89 | 8.10 | 8.14 | 1.26 |
| PHILIPPINES | 0.09 | 0.37 | 0.28 | 0.20 |
| SDLM | 0.15 | 0.16 | 0.02 | 0.08 |
| ASO SPARES | 12.56 | 10.88 | 14.47 | 12.64 |
| OTHER | 1.97 | 11.16 | 33.38 | 53.29 |
| OTHER | 1.27 | 4.79 | 11.36 | 9.56 |
| TOTAL AERO PRODUCTS | 157.52 | 211.10 | 266.48 | 301.13 |
| TOTAL MISSILES & ADV. PROGRAMS | 5.29 | 0.00 | 0.00 | 0.00 |
| TOTAL LTV VOUGHT | 162.81 | 211.10 | 266.48 | 301.13 |
| PROFIT ADJUSTMENT PERCENT 7.00% | 1.12 | 5.20 | 0.65 | -0.53 |
| ADJUSTED TOTAL | 163.94 | 216.30 | 267.12 | 300.59 |

## 1984 ANNUAL OPERATING PLAN, APRIL REVISION - QUALITY ASSURANCE

| ITEM | BASELINE $(000) | AOP BUDGETS $(000) | | |
|---|---|---|---|---|
| | 1983 | 1984 | 1985 | 1986 |
| EQUIV.DIV.IMPRVMNT | BASE | 9.70 | 3.38 | 3.46 |
| BUY - PERCENT OF COSTS | 22.54 | 27.14 | 30.10 | 28.38 |
| MAKE - PERCENT OF COSTS | 77.46 | 72.86 | 69.90 | 71.62 |
| SALES+CHANGE IN INVENTORY | 163937 | 216298 | 267123 | 300593 |
| LABOR | | | | |
| DIRECT - SALARY & WAGES | 5163 | 4771 | 5344 | 5821 |
| OTHER DIRECT CHARGES | 670 | 638 | 715 | 779 |
| INDIRECT - SALARY & WAGES | 732 | 821 | 920 | 1002 |
| FRINGES | 2730 | 2567 | 2875 | 3132 |
| TOTAL LABOR | 9294 | 8798 | 9854 | 10733 |
| MATERIAL | | | | |
| DIRECT | 0 | 0 | 0 | 0 |
| ODC | 446 | 425 | 477 | 519 |
| INDIRECT | | | | |
| SUPPLIES & EXPENSES | 191 | 601 | 674 | 734 |
| CREDITS | 0 | 0 | 0 | 0 |
| TOTAL MATERIAL | 637 | 1027 | 1150 | 1253 |
| ENERGY | 0 | 0 | 0 | 0 |
| CAPITAL | | | | |
| LEASE COSTS | 60 | 61 | 68 | 74 |
| INSURANCE,RENT,TAXES | 100 | 80 | 90 | 98 |
| DEPRECIATION & AMORT. | 185 | 171 | 192 | 209 |
| <<< TOTAL >>> | 10277 | 10137 | 11354 | 12367 |
| MEMO: ALLOCATIONS | | | | |
| DATA PROCESSING | 7 | 12 | 14 | 15 |
| HUMAN RESOURCES | 327.6 | 315.9 | 354 | 385 |
| FACILITIES | 444.21 | 421.98 | 473 | 515 |
| OTHER - DACOL | 0 | 14.43 | 16 | 18 |
| TOTAL+ALLOCATIONS | 11055 | 10902 | 12210 | 13299 |

NOMINAL CHALLENGE BUDGETS, APRIL REVISION - QUALITY ASSURANCE

| ITEM | BASELINE $(000) 1983 | AOP BUDGETS $(000) 1984 | 1985 | 1986 |
|---|---|---|---|---|
| EQUIV.DIV.IMPRVMNT | BASE | 3.00 | 4.00 | 4.00 |
| BUY - PERCENT OF COSTS | 22.54 | 27.14 | 30.10 | 28.38 |
| MAKE - PERCENT OF COSTS | 77.46 | 72.86 | 69.90 | 71.62 |
| SALES+CHANGE IN INVENTORY | 163937 | 216298 | 267123 | 300593 |
| LABOR | | | | |
| DIRECT - SALARY & WAGES | 5163 | 6075 | 6784 | 7353 |
| OTHER DIRECT CHARGES | 670 | 788 | 880 | 954 |
| INDIRECT - SALARY & WAGES | 732 | 861 | 961 | 1042 |
| FRINGES | 2730 | 3213 | 3588 | 3889 |
| TOTAL LABOR | 9294 | 10937 | 12212 | 13237 |
| MATERIAL | | | | |
| DIRECT | 0 | 0 | 0 | 0 |
| ODC | 446 | 536 | 620 | 700 |
| INDIRECT | | | | |
| SUPPLIES & EXPENSES | 191 | 230 | 266 | 300 |
| CREDITS | 0 | 0 | 0 | 0 |
| TOTAL MATERIAL | 637 | 766 | 886 | 1000 |
| ENERGY | 0 | 0 | 0 | 0 |
| CAPITAL | | | | |
| LEASE COSTS | 60 | 70 | 78 | 83 |
| INSURANCE,RENT,TAXES | 100 | 117 | 131 | 140 |
| DEPRECIATION & AMORT. | 185 | 217 | 241 | 259 |
| <<< TOTAL >>> | 10277 | 12107 | 13547 | 14720 |
| MEMO: ALLOCATIONS | | | | |
| DATA PROCESSING | 7 | 8 | 9 | 10 |
| HUMAN RESOURCES | 328 | 397 | 454 | 500 |
| FACILITIES | 444 | 538 | 615 | 678 |
| OTHER - DACOL | 0 | 0 | 0 | 0 |
| TOTAL+ALLOCATIONS | 11055 | 13050 | 14625 | 15908 |

## CHALLENGE BUDGETS

- THE TOTAL FACTOR PRODUCTIVITY MODEL CALCULATES CHALLENGE BUDGETS USING BASE YEAR FINANCIAL DATA, PRODUCTIVITY IMPROVEMENT TARGET, AND FORECASTS FOR OUTPUT AND INFLATION.
- FOR SIMPLICITY, THE EXAMPLE SHOWS CHALLENGE BUDGET CALCULATIONS FOR TOTAL COSTS ONLY. HOWEVER, THE TOTAL FACTOR MODEL CALCULATES CHALLENGE BUDGETS FOR CATEGORIES AND SUB-CATEGORIES OF LABOR, MATERIALS, ENERGY, AND CAPITAL.

SALES - COMPANY

EXAMPLE

| CONTRACT | $(000,000) | | | |
|---|---|---|---|---|
| | 1983 BASE | 1984 | 1985 | 1986 |
| DIVISION A: | | | | |
| PROGRAM A | 11.15 | 11.54 | 12.31 | 13.63 |
| PROGRAM B | 12.40 | 14.51 | 14.35 | 26.29 |
| PROGRAM C | 9.48 | 6.75 | 6.88 | 10.92 |
| PROGRAM D | 4.41 | 5.11 | 8.84 | 8.70 |
| PROGRAM E | 12.52 | 7.41 | 6.47 | 6.26 |
| PROGRAM F | 41.42 | 37.67 | 99.67 | 139.04 |
| PROGRAM G | 10.57 | 7.84 | 6.76 | 6.66 |
| PROGRAM H | 18.29 | 3.20 | 0.42 | 0.00 |
| PROGRAM I | 5.50 | 5.30 | 0.67 | 0.18 |
| PROGRAM J | 21.76 | 15.09 | 34.54 | 22.38 |
| PROGRAM K | 3.86 | 9.13 | 34.17 | 4.44 |
| PROGRAM L | 0.16 | 0.82 | 0.63 | 0.44 |
| PROGRAM M | 1.05 | 1.76 | 1.08 | 1.24 |
| PROGRAM N | 12.09 | 10.88 | 12.77 | 11.50 |
| PROGRAM O | 19.70 | 37.21 | 83.44 | 106.58 |
| PROGRAM P | 3.28 | 5.38 | 8.93 | 9.95 |
| TOTAL DIVISION A | 187.63 | 179.60 | 331.93 | 368.24 |
| TOTAL DIVISION B | 127.45 | 166.06 | 174.95 | 202.33 |
| TOTAL COMPANY | 315.08 | 345.66 | 506.88 | 570.57 |

INVENTORY - COMPANY

EXAMPLE

| CONTRACT | $(000,000) | | | | |
|---|---|---|---|---|---|
| | 1982 | 1983 BASE | 1984 | 1985 | 1986 |
| DIVISION A: | | | | | |
| PROGRAM A | 10.03 | 9.57 | 14.94 | 12.83 | 11.63 |
| PROGRAM B | 17.42 | 19.34 | 17.86 | 20.08 | 16.54 |
| PROGRAM C | 7.13 | 4.67 | 4.17 | 3.76 | 4.32 |
| PROGRAM D | 3.03 | 2.49 | 4.21 | 5.01 | 4.54 |
| PROGRAM E | 8.04 | 4.20 | 3.08 | 2.56 | 0.80 |
| PROGRAM F | 19.90 | 40.98 | 103.43 | 111.81 | 105.48 |
| PROGRAM G | 2.40 | -0.29 | 2.30 | 1.46 | 1.09 |
| PROGRAM H | 7.04 | 0.16 | 0.00 | .00 | 0.00 |
| PROGRAM I | 1.65 | 0.71 | 0.41 | 0.16 | 0.05 |
| PROGRAM J | 5.89 | 7.46 | 9.52 | 14.97 | 21.11 |
| PROGRAM K | 1.32 | 8.32 | 17.20 | 1.13 | -0.51 |
| PROGRAM L | -0.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| PROGRAM M | 0.04 | 0.46 | 0.35 | -0.49 | -0.90 |
| PROGRAM N | 0.16 | 0.63 | 0.63 | 2.33 | 3.46 |
| PROGRAM O | -0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| PROGRAM P | 0.19 | -1.82 | -2.41 | 0.02 | -0.36 |
| TOTAL DIVISION A | 84.18 | 96.88 | 175.70 | 175.63 | 167.27 |
| TOTAL DIVISION B | 4.18 | 11.40 | 15.05 | 15.67 | 21.67 |
| TOTAL COMPANY | 88.36 | 108.28 | 190.75 | 191.30 | 188.94 |

**CHANGE IN INVENTORY - COMPANY**

**EXAMPLE**

| CONTRACT | | $(000,000) | | | |
|---|---|---|---|---|---|
| | | 1983 BASE | 1984 | 1985 | 1986 |
| **DIVISION A:** | | | | | |
| PROGRAM A | | -0.46 | 5.37 | -2.11 | -1.20 |
| PROGRAM B | | 1.92 | -1.47 | 2.21 | -3.53 |
| PROGRAM C | | -2.46 | -0.49 | -0.42 | 0.56 |
| PROGRAM D | | -0.54 | 1.72 | 0.80 | -0.47 |
| PROGRAM E | | -3.85 | -1.11 | -0.52 | -1.76 |
| PROGRAM F | | 21.09 | 62.45 | 8.38 | -6.33 |
| PROGRAM G | | -2.69 | 2.59 | -0.84 | -0.37 |
| PROGRAM H | | -6.88 | -0.16 | .00 | .00 |
| PROGRAM I | | -0.94 | -0.30 | -0.25 | -0.11 |
| PROGRAM J | | 1.58 | 2.05 | 5.45 | 6.14 |
| PROGRAM K | | 7.00 | 8.88 | -16.07 | -1.63 |
| PROGRAM L | | 0.03 | 0.00 | 0.00 | 0.00 |
| PROGRAM M | | 0.42 | -0.11 | -0.84 | -0.40 |
| PROGRAM N | | 0.47 | .00 | 1.70 | 1.13 |
| PROGRAM O | | 0.01 | 0.00 | 0.00 | 0.00 |
| PROGRAM P | | -2.00 | -0.59 | 2.43 | -0.38 |
| TOTAL DIVISION A | | 12.70 | 78.82 | -0.06 | -8.36 |
| TOTAL DIVISION B | | 7.23 | 3.65 | 0.62 | 6.00 |
| TOTAL COMPANY | | 19.92 | 82.46 | 0.56 | -2.37 |
| PROFIT ADJUSTMENT ON INVENTORY | 7.00% | 1.39 | 5.77 | 0.04 | -0.17 |
| ADJUSTED TOTAL | | 21.32 | 88.24 | 0.59 | -2.53 |

SALES + CHANGE IN INVENTORY - COMPANY

EXAMPLE

| CONTRACT | | $(000,000) | | | |
|---|---|---|---|---|---|
| | | 1983 BASE | 1984 | 1985 | 1986 |
| DIVISION A: | | | | | |
| PROGRAM A | | 10.70 | 16.91 | 10.20 | 12.43 |
| PROGRAM B | | 14.32 | 13.03 | 16.57 | 22.76 |
| PROGRAM C | | 7.02 | 6.25 | 6.47 | 11.49 |
| PROGRAM D | | 3.86 | 6.83 | 9.64 | 8.23 |
| PROGRAM E | | 8.67 | 6.30 | 5.94 | 4.50 |
| PROGRAM F | | 62.50 | 100.12 | 108.05 | 132.72 |
| PROGRAM G | | 7.88 | 10.43 | 5.92 | 6.29 |
| PROGRAM H | | 11.42 | 3.03 | 0.42 | .00 |
| PROGRAM I | | 4.55 | 5.01 | 0.42 | 0.07 |
| PROGRAM J | | 23.34 | 17.15 | 40.00 | 28.52 |
| PROGRAM K | | 10.86 | 18.00 | 18.10 | 2.81 |
| PROGRAM L | | 0.19 | 0.82 | 0.63 | 0.44 |
| PROGRAM M | | 1.48 | 1.65 | 0.24 | 0.84 |
| PROGRAM N | | 12.56 | 10.88 | 14.47 | 12.64 |
| PROGRAM O | | 19.70 | 37.21 | 83.44 | 106.58 |
| PROGRAM P | | 1.27 | 4.79 | 11.36 | 9.56 |
| TOTAL DIVISION A | | 200.32 | 258.41 | 331.87 | 359.88 |
| TOTAL DIVISION B | | 134.68 | 169.71 | 175.57 | 208.33 |
| TOTAL COMPANY | | 335.00 | 428.12 | 507.44 | 568.20 |
| PROFIT ADJUSTMENT ON INVENTORY | 7.00% | 1.39 | 5.77 | 0.04 | -0.17 |
| ADJUSTED TOTAL | | 336.40 | 433.89 | 507.48 | 568.04 |

PERCENT INVOLVEMENT IN OUTPUT - DIVISION A

EXAMPLE

| CONTRACT | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|
| DIVISION A | | | | |
| PROGRAM A | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM B | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM C | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM D | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM E | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM F | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM G | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM H | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM I | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM J | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM K | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM L | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM M | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM N | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM O | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM P | 100.00 | 100.00 | 100.00 | 100.00 |
| DIVISION B PROGRAMS | 100.00 | 0.00 | 0.00 | 0.00 |

**SALES + CHANGE IN INVENTORY - DIVISION A**

EXAMPLE

| CONTRACT | | $(000,000) | | | |
|---|---|---|---|---|---|
| | | 1983 BASE | 1984 | 1985 | 1986 |
| DIVISION A | | | | | |
| PROGRAM A | | 10.70 | 16.91 | 10.20 | 12.43 |
| PROGRAM B | | 14.32 | 13.03 | 16.57 | 22.76 |
| PROGRAM C | | 7.02 | 6.25 | 6.47 | 11.49 |
| PROGRAM D | | 3.86 | 6.83 | 9.64 | 8.23 |
| PROGRAM E | | 8.67 | 6.30 | 5.94 | 4.50 |
| PROGRAM F | | 62.50 | 100.12 | 108.05 | 132.72 |
| PROGRAM G | | 7.88 | 10.43 | 5.92 | 6.29 |
| PROGRAM H | | 11.42 | 3.03 | 0.42 | .00 |
| PROGRAM I | | 4.55 | 5.01 | 0.42 | 0.07 |
| PROGRAM J | | 23.34 | 17.15 | 40.00 | 28.52 |
| PROGRAM K | | 10.86 | 18.00 | 18.10 | 2.81 |
| PROGRAM L | | 0.19 | 0.82 | 0.63 | 0.44 |
| PROGRAM M | | 1.48 | 1.65 | 0.24 | 0.84 |
| PROGRAM N | | 12.56 | 10.88 | 14.47 | 12.64 |
| PROGRAM O | | 19.70 | 37.21 | 83.44 | 106.58 |
| PROGRAM P | | 1.27 | 4.79 | 11.36 | 9.56 |
| TOTAL DIVISION A | | 200.32 | 258.41 | 331.87 | 359.88 |
| TOTAL DIVISION B | | 75.02 | 0.00 | 0.00 | 0.00 |
| TOTAL COMPANY | | 275.35 | 258.41 | 331.87 | 359.88 |
| PROFIT ADJUSTMENT ON INVENTORY | 7.00% | 1.01 | 5.52 | .00 | -0.59 |
| ADJUSTED TOTAL | | 276.36 | 263.93 | 331.86 | 359.29 |

1984 ANNUAL OPERATING PLAN - DIVISION A

EXAMPLE

| ITEM | BASELINE $(000) 1983 | AOP BUDGETS $(000) 1984 | 1985 | 1986 |
|---|---|---|---|---|
| EQUIV.DIV.IMPRVMNT | BASE | 1.66 | 3.25 | 3.90 |
| BUY - PERCENT OF COSTS | 22.54 | 27.14 | 30.10 | 28.38 |
| MAKE - PERCENT OF COSTS | 77.46 | 72.86 | 69.90 | 71.62 |
| SALES+CHANGE IN INVENTORY | 276358 | 263929 | 331859 | 359291 |
| LABOR | | | | |
| DIRECT - SALARY & WAGES | 57797 | 51596 | 61134 | 65726 |
| OTHER DIRECT CHARGES | 15836 | 10693 | 8059 | 9973 |
| INDIRECT - SALARY & WAGES | 36933 | 32375 | 38662 | 40662 |
| FRINGES | 36293 | 32786 | 44667 | 48308 |
| TOTAL LABOR | 146860 | 127449 | 152522 | 164668 |
| MATERIAL | | | | |
| DIRECT | 55158 | 63417 | 88908 | 88325 |
| ODC | 10557 | 7128 | 5373 | 6648 |
| INDIRECT | | | | |
| SUPPLIES & EXPENSES | 10740 | 10780 | 11828 | 11318 |
| CREDITS | -699 | -910 | -631 | -862 |
| NON DEPARTMENT | 0 | 0 | 0 | 0 |
| OTHER | 0 | 0 | 0 | 0 |
| TOTAL MATERIAL | 75756 | 80416 | 105477 | 105430 |
| ENERGY | 4130 | 4090 | 4787 | 5575 |
| CAPITAL | | | | |
| LEASE COSTS | 1716 | 1855 | 3209 | 3494 |
| INSURANCE, RENT, TAXES | 7582 | 5950 | 6631 | 6871 |
| DEPRECIATION & AMORT. | 2198 | 1858 | 2084 | 2575 |
| <<< TOTAL >>> | 238242 | 221619 | 274711 | 288613 |
| MEMO: ALLOCATIONS | | | | |
| DIVISIONAL & CORPORATE | 6496 | 7172 | 8291 | 7880 |
| TOTAL+ALLOCATIONS | 244738 | 228790 | 283002 | 296492 |

NOMINAL CHALLENGE BUDGETS - DIVISION A

EXAMPLE

| ITEM | BASELINE $(000) 1983 | AOP BUDGETS $(000) 1984 | 1985 | 1986 |
|---|---|---|---|---|
| EQUIV.DIV.IMPRVMNT | BASE | 3.00 | 4.00 | 4.00 |
| BUY - PERCENT OF COSTS | 22.54 | 27.14 | 30.10 | 28.38 |
| MAKE - PERCENT OF COSTS | 77.46 | 72.86 | 69.90 | 71.62 |
| SALES+CHANGE IN INVENTORY | 276358 | 263929 | 331859 | 359291 |
| LABOR | | | | |
| DIRECT - SALARY & WAGES | 57797 | 49231 | 55968 | 58368 |
| OTHER DIRECT CHARGES | 15836 | 13489 | 15335 | 15993 |
| INDIRECT - SALARY & WAGES | 36933 | 31459 | 35765 | 37299 |
| FRINGES | 36293 | 30914 | 35145 | 36652 |
| TOTAL LABOR | 146860 | 125093 | 142213 | 148312 |
| MATERIAL | | | | |
| DIRECT | 55158 | 63245 | 89038 | 89572 |
| ODC | 10557 | 9182 | 10815 | 11750 |
| INDIRECT | | | | |
| SUPPLIES & EXPENSES | 10740 | 9341 | 11002 | 11954 |
| CREDITS | -699 | -802 | -1129 | -1136 |
| NON DEPARTMENT | 0 | 0 | 0 | 0 |
| OTHER | 0 | 0 | 0 | 0 |
| TOTAL MATERIAL | 75756 | 80966 | 109725 | 112141 |
| ENERGY | 4130 | 3585 | 4223 | 4510 |
| CAPITAL | | | | |
| LEASE COSTS | 1716 | 1458 | 1650 | 1706 |
| INSURANCE,RENT,TAXES | 7582 | 6440 | 7290 | 7534 |
| DEPRECIATION & AMORT. | 2198 | 1867 | 2113 | 2184 |
| <<< TOTAL >>> | 238242 | 219408 | 267216 | 276386 |
| MEMO: ALLOCATIONS | | | | |
| DIVISIONAL & CORPORATE | 6496 | 5699 | 6633 | 7036 |
| TOTAL+ALLOCATIONS | 244738 | 225107 | 273849 | 283422 |

PERCENT INVOLVEMENT IN OUTPUT - FUNCTION Z

EXAMPLE

| CONTRACT | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|
| DIVISION A | | | | |
| PROGRAM A | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM B | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM C | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM D | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM E | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM F | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM G | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM H | 4.00 | 4.00 | 4.00 | 4.00 |
| PROGRAM I | 4.00 | 4.00 | 4.00 | 4.00 |
| PROGRAM J | 90.00 | 90.00 | 90.00 | 90.00 |
| PROGRAM K | 45.00 | 45.00 | 45.00 | 45.00 |
| PROGRAM L | 45.00 | 45.00 | 45.00 | 45.00 |
| PROGRAM M | 10.00 | 10.00 | 10.00 | 10.00 |
| PROGRAM N | 100.00 | 100.00 | 100.00 | 100.00 |
| PROGRAM O | 10.00 | 30.00 | 40.00 | 50.00 |
| PROGRAM P | 100.00 | 100.00 | 100.00 | 100.00 |
| DIVISION B PROGRAMS | 5.00 | 0.00 | 0.00 | 0.00 |

SALES + CHANGE IN INVENTORY - FUNCTION Z

EXAMPLE

| CONTRACT | | $(000,000) | | | |
|---|---|---|---|---|---|
| | | 1983 BASE | 1984 | 1985 | 1986 |
| DIVISION A | | | | | |
| PROGRAM A | | 10.70 | 16.91 | 10.20 | 12.43 |
| PROGRAM B | | 14.32 | 13.03 | 16.57 | 22.76 |
| PROGRAM C | | 7.02 | 6.25 | 6.47 | 11.49 |
| PROGRAM D | | 3.86 | 6.83 | 9.64 | 8.23 |
| PROGRAM E | | 8.67 | 6.30 | 5.94 | 4.50 |
| PROGRAM F | | 62.50 | 100.12 | 108.05 | 132.72 |
| PROGRAM G | | 7.88 | 10.43 | 5.92 | 6.29 |
| PROGRAM H | | 0.46 | 0.12 | 0.02 | .00 |
| PROGRAM I | | 0.18 | 0.20 | 0.02 | .00 |
| PROGRAM J | | 21.00 | 15.43 | 36.00 | 25.67 |
| PROGRAM K | | 4.89 | 8.10 | 8.14 | 1.26 |
| PROGRAM L | | 0.09 | 0.37 | 0.28 | 0.20 |
| PROGRAM M | | 0.15 | 0.16 | 0.02 | 0.08 |
| PROGRAM N | | 12.56 | 10.88 | 14.47 | 12.64 |
| PROGRAM O | | 1.97 | 11.16 | 33.38 | 53.29 |
| PROGRAM P | | 1.27 | 4.79 | 11.36 | 9.56 |
| TOTAL DIVISION A | | 157.52 | 211.10 | 266.48 | 301.13 |
| TOTAL DIVISION B | | 5.29 | 0.00 | 0.00 | 0.00 |
| TOTAL COMPANY | | 162.81 | 211.10 | 266.48 | 301.13 |
| PROFIT ADJUSTMENT ON INVENTORY | 7.00% | 1.12 | 5.20 | 0.65 | -0.53 |
| ADJUSTED TOTAL | | 163.94 | 216.30 | 267.12 | 300.59 |

1984 ANNUAL OPERATING PLAN - FUNCTION Z

EXAMPLE

| ITEM | BASELINE $(000) 1983 | AOP BUDGETS $(000) 1984 | 1985 | 1986 |
|---|---|---|---|---|
| EQUIV. IMPROVEMENT | BASE | 9.70 | 3.38 | 3.46 |
| BUY - PERCENT OF COSTS | 22.54 | 27.14 | 30.10 | 28.38 |
| MAKE - PERCENT OF COSTS | 77.46 | 72.86 | 69.90 | 71.62 |
| SALES+CHANGE IN INVENTORY | 163937 | 216298 | 267123 | 300593 |
| LABOR | | | | |
| DIRECT - SALARY & WAGES | 5163 | 4771 | 5344 | 5821 |
| OTHER DIRECT CHARGES | 670 | 638 | 715 | 779 |
| INDIRECT - SALARY & WAGES | 732 | 821 | 920 | 1002 |
| FRINGES | 2730 | 2567 | 2875 | 3132 |
| TOTAL LABOR | 9294 | 8798 | 9854 | 10733 |
| MATERIAL | | | | |
| DIRECT | 0 | 0 | 0 | 0 |
| ODC | 446 | 425 | 477 | 519 |
| INDIRECT | | | | |
| SUPPLIES & EXPENSES | 191 | 601 | 674 | 734 |
| CREDITS | 0 | 0 | 0 | 0 |
| TOTAL MATERIAL | 637 | 1027 | 1150 | 1253 |
| ENERGY | 0 | 0 | 0 | 0 |
| CAPITAL | | | | |
| LEASE COSTS | 60 | 61 | 68 | 74 |
| INSURANCE, RENT, TAXES | 100 | 80 | 90 | 98 |
| DEPRECIATION & AMORT. | 185 | 171 | 192 | 209 |
| <<< TOTAL >>> | 10277 | 10137 | 11354 | 12367 |
| MEMO: ALLOCATIONS | | | | |
| DATA PROCESSING | 7 | 12 | 14 | 15 |
| HUMAN RESOURCES | 327.6 | 315.9 | 354 | 385 |
| FACILITIES | 444.21 | 421.98 | 473 | 515 |
| OTHER - DACOL | 0 | 14.43 | 16 | 18 |
| TOTAL+ALLOCATIONS | 11055 | 10902 | 12210 | 13299 |

NOMINAL CHALLENGE BUDGETS - FUNCTION Z

EXAMPLE

| ITEM | BASELINE $(000) 1983 | AOP BUDGETS $(000) 1984 | 1985 | 1986 |
|---|---|---|---|---|
| EQUIV. IMPROVEMENT | BASE | 3.00 | 4.00 | 4.00 |
| BUY - PERCENT OF COSTS | 22.54 | 27.14 | 30.10 | 28.38 |
| MAKE - PERCENT OF COSTS | 77.46 | 72.86 | 69.90 | 71.62 |
| SALES+CHANGE IN INVENTORY | 163937 | 216298 | 267123 | 300593 |
| LABOR | | | | |
| DIRECT - SALARY & WAGES | 5163 | 6075 | 6784 | 7353 |
| OTHER DIRECT CHARGES | 670 | 788 | 880 | 954 |
| INDIRECT - SALARY & WAGES | 732 | 861 | 961 | 1042 |
| FRINGES | 2730 | 3213 | 3588 | 3889 |
| TOTAL LABOR | 9294 | 10937 | 12212 | 13237 |
| MATERIAL | | | | |
| DIRECT | 0 | 0 | 0 | 0 |
| ODC | 446 | 536 | 620 | 700 |
| INDIRECT | | | | |
| SUPPLIES & EXPENSES | 191 | 230 | 266 | 300 |
| CREDITS | 0 | 0 | 0 | 0 |
| TOTAL MATERIAL | 637 | 766 | 886 | [illegible] |
| ENERGY | 0 | 0 | 0 | 0 |
| CAPITAL | | | | |
| LEASE COSTS | 60 | 70 | 78 | [illegible] |
| INSURANCE,RENT,TAXES | 100 | 117 | 131 | [illegible] |
| DEPRECIATION & AMORT. | 185 | [illegible] | 241 | [illegible] |
| <<< TOTAL >>> | 10277 | 12107 | 13547 | 14720 |
| MEMO: ALLOCATIONS | | | | |
| DATA PROCESSING | 7 | 8 | 9 | 10 |
| HUMAN RESOURCES | 328 | 397 | 454 | 500 |
| FACILITIES | 444 | 538 | 615 | 678 |
| OTHER - DACOL | 0 | 0 | 0 | 0 |
| TOTAL+ALLOCATIONS | 11055 | 13050 | 14625 | 15908 |

## DUAL FUNCTION COST MODEL

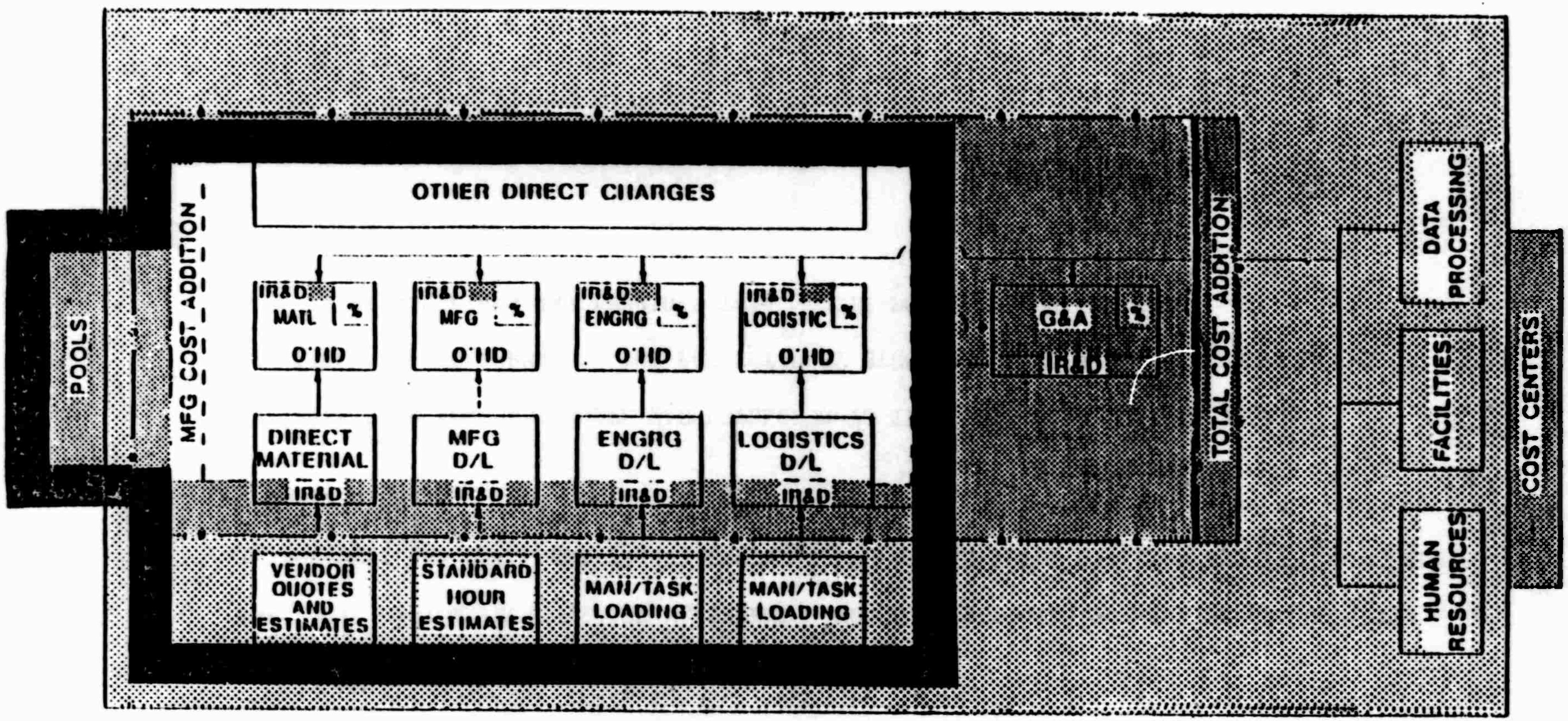
- THE TOTAL FACTOR PRODUCTIVITY MEASUREMENT MODEL IS DESIGNED TO PROVIDE PRODUCTIVITY IMPROVEMENT AND CHALLENGE BUDGET INFORMATION FOR THE TOTAL DIVISION AND ITS COMPONENT ORGANIZATIONS.

- THE DUAL FUNCTION COST MODEL WAS DEVELOPED TO TRANSLATE DATA THAT IS READILY AVAILABLE IN THE FORMAT OF THE PRESENT COST STRUCTURE INTO A FORMAT THAT FOLLOWS ORGANIZATIONAL LINES AND PROVIDES TOTAL COSTS FOR EACH ORGANIZATION.

PRODUCTIVITY

LTV Aerospace and Defense
Vought Aero Products Division

# PRESENT COST STRUCTURE




P3-1212-41

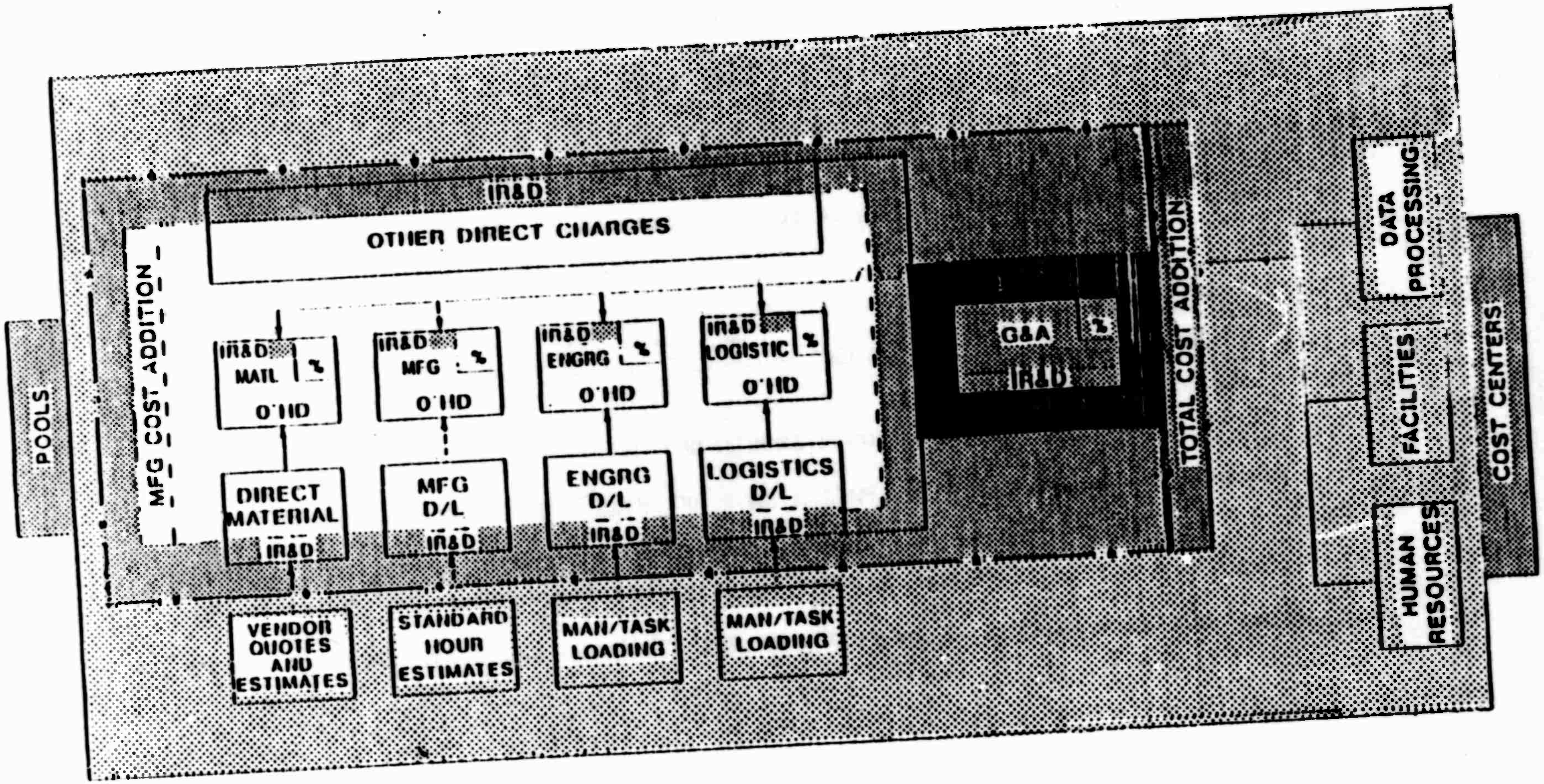
## PRESENT COST STRUCTURE

- DIRECT AND OVERHEAD COSTS ARE COLLECTED IN "POOLS." IN THIS EXAMPLE THE POOLS ARE MATERIALS, MANUFACTURING, ENGINEERING, AND LOGISTICS.
- VENDOR QUOTES AND ESTIMATES, STANDARD HOUR ESTIMATES, AND MAN/TASK LOADING ARE USED TO DETERMINE DIRECT MATERIAL AND DIRECT LABOR (D/L) COSTS.
- INDIRECT COSTS THAT SUPPORT DIRECT FUNCTIONS AND ACTIVITIES ARE COLLECTED IN OVERHEAD (O'HD) ACCOUNTS.
- THE RATIO OF INDIRECT TO DIRECT COSTS IS THAT FUNCTION'S OVERHEAD RATE. THESE RATES ARE USED IN PRICING NEW CONTRACTS.
- OTHER DIRECT CHARGES (ODCs) ARE COSTS THAT ARE DIRECTLY CHARGEABLE TO CONTRACTS BUT THAT ARE NOT CLASSIFIED AS EITHER DIRECT LABOR OR DIRECT MATERIAL.
- MANUFACTURING COST ADDITIONS ARE THE SUM OF ODCs, DIRECT AND OVERHEAD COSTS MINUS INDEPENDENT RESEARCH AND DEVELOPMENT (IR&D) COSTS.

PRODUCTIVITY

LTV Aerospace and Defense
Vought Aero Products Division

# PRESENT COST STRUCTURE

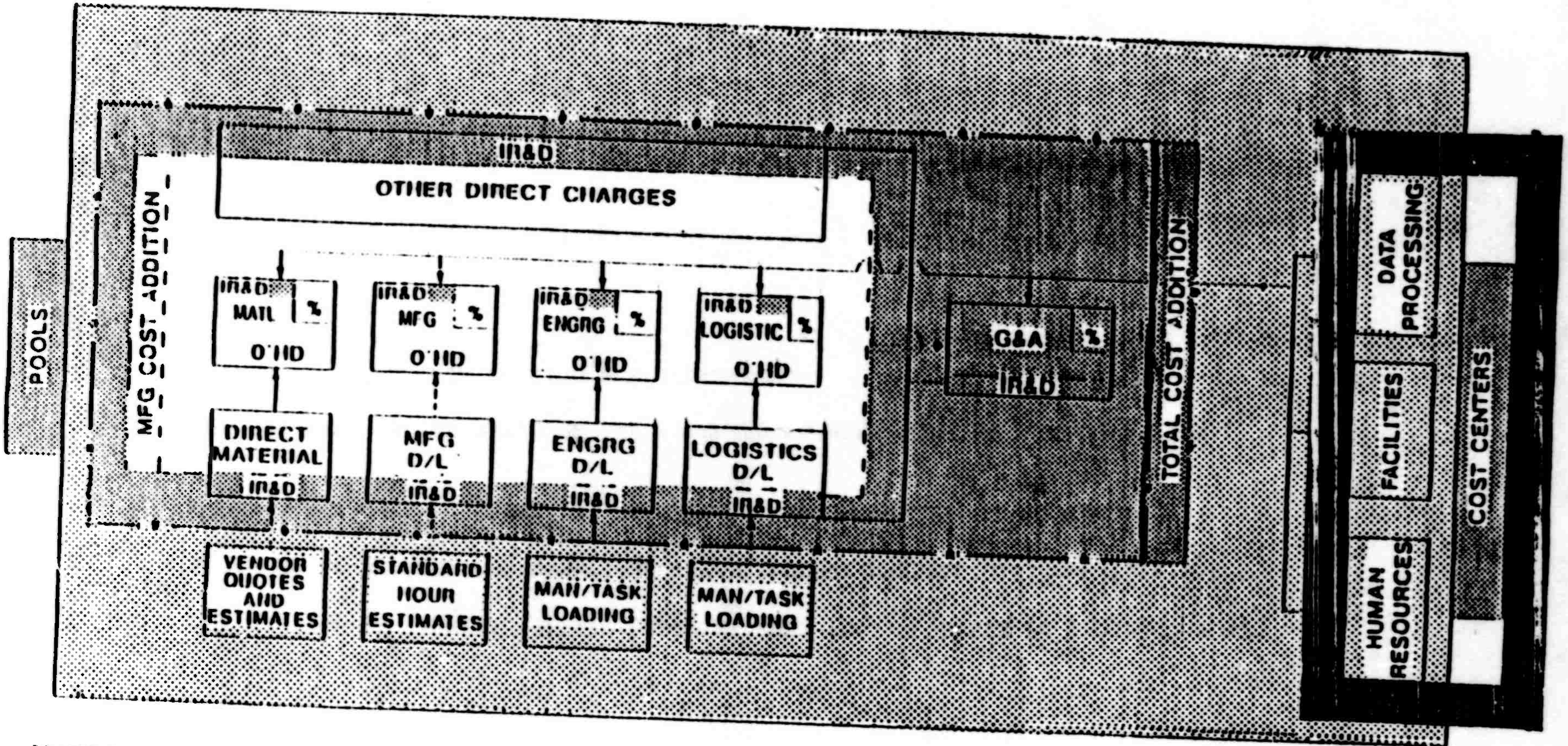



P3-1212-41

## PRESENT COST STRUCTURE

- THE GENERAL AND ADMINISTRATIVE (G&A) EXPENSE POOL CONSISTS OF INDIRECT COSTS INCURRED BY SUPPORT ORGANIZATIONS WHICH INCLUDE GENERAL MANAGEMENT, FINANCE, PROGRAM MANAGEMENT, PLANNING, MARKETING, AND CORPORATE ALLOCATIONS.
- THE G&A RATE IS THE RATIO OF G&A EXPENSES TO MANUFACTURING COST ADDITIONS. THIS RATE IS USED IN PRICING NEW CONTRACTS.

# PRESENT COST STRUCTURE




P3-1212-41

## PRESENT COST STRUCTURE

- HUMAN RESOURCES, FACILITIES, AND DATA PROCESSING COSTS ARE COLLECTED IN INDIVIDUAL "COST CENTERS."
- THE COST CENTERS ALLOCATE THEIR COSTS TO THE POOLS AS INDIRECT COSTS, AND THEY BECOME PART OF EACH POOL'S OVERHEAD RATE AND PART OF THE G&A RATE.

PRODUCTIVITY

LTV Aerospace and Defense
Vought Aero Products Division

# BUILDING BLOCK APPROACH TO COSTS

| | | | | | | |
|---|---|---|---|---|---|---|
| COST OF SALES | = | MATERIALS COSTS | + | MANUFAC- TURING COSTS | + | ENGINEER- ING COSTS |
| | + | HUMAN RESOURCES COST | + | FACILITIES COSTS | + | DATA PROCESSING COSTS |
| | + | LOGISTICS COSTS | + | ODC COSTS | + | FINANCE AND G&A COSTS |

## BUILDING BLOCK APPROACH TO COSTS

- IN THE BUILDING BLOCK APPROACH, ALL COSTS ARE TREATED AS IF THEY WERE DIRECT COSTS.
- TRADITIONAL FINANCIAL DATA CAN BE TRANSLATED INTOTHE BUILDING BLOCK FORMAT AS SHOWN IN THE FOLLOWING PAGES.

DIVISION DATA (BY POOL/COST CENTER) YEAR: DATA: SHEET 1 OF 2

| DESCRIPTION | MATERIAL | MFGRNG | VOMC | FMC | BREGG CT | ENGRNG | LOGISTICS | G&A | FACILITY | HUM RES | DATA PRO | ODC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LABOR | | | | | | | | | | | | | |
| DIRECT BASE | | 32641 | 3311 | 122 | 1130 | 11825 | 2560 | | | | | | 51596 |
| INDIRECT LABOR: | | | | | | | | | | | | | |
| SALARIES & WAGES | 3106 | 8041 | 429 | 39 | 282 | 810 | 146 | 4049 | 4450 | 1620 | 2828 | | 26680 |
| OVERTIME | 78 | 534 | 6 | 8 | 15 | 8 | 1 | 141 | | 228 | | | 1018 |
| DIRECT ON INDIR | | 1830 | 39 | 18 | 9 | 1240 | 254 | | | | | | 3390 |
| TRAINING | | 356 | 21 | 2 | | | | | | | | | 379 |
| ABSENCES | | | | | | 126 | 35 | | | | | | 161 |
| PRODUCTIVITY AND | | 570 | 67 | | 38 | | | | | | | | 675 |
| OTHER | | | | | | | | 55 | | 16 | | | 71 |
| FRINGE BENEFITS | 755 | 19726 | 1938 | 59 | 660 | 3779 | 1090 | 1076 | 2090 | 672 | 940 | | 32796 |
| | 4019 | 64505 | 5811 | 241 | 2134 | 17797 | 4086 | 5321 | 6540 | 2536 | 3767 | 0 | 116757 |
| MATERIAL | | | | | | | | | | | | | |
| DIRECT MATERIAL | 63417 | | | | | | | | | | | | 63417 |
| SUPPLIES & EXPENSE: | | | | | | | | | | | | | |
| TRAVEL | 104 | 192 | 3 | 2 | | 96 | 26 | 446 | | | | | 869 |
| COMMUNICATION | 88 | 244 | 12 | 1 | 14 | 134 | 66 | 138 | | 25 | | | 714 |
| FREIGHT NON-PROD | 34 | | | | | | | | | | | | 34 |
| TRUCK & TRANSP | | | | | | | | | | | | | 0 |
| OFFICE SUPPLIES | 21 | 123 | 4 | | | 28 | 10 | | | | | | 186 |
| OFFICE ACCESSORY | | | | | | 46 | 4 | | | | | | 50 |
| REPRODUCTION | 28 | 218 | 8 | 1 | | 52 | 20 | 167 | | 54 | | | 544 |
| EMPLOYEE RELOC | | | | | | | | | | 578 | | | 578 |
| PERISHABLE TOOLS | | 632 | 14 | 31 | 62 | | | | | | | | 739 |
| FACTORY ACCESSOR | | 318 | | | 12 | 30 | | | | | | | 353 |
| SHOP SUPPLIES | | 74 | | | | 31 | 0 | | | | | | 105 |
| OTHER SUPPLIES | | 22 | | | | 2 | 1 | | | 12 | | | 37 |
| PUR LAB REL EXP | | | | | | 1007 | | | | | | | 1007 |
| OTHER | 183 | 1144 | 17 | 0 | 109 | 53 | 4 | 624 | 2450 | 511 | 269 | | 5366 |
| CREDITS | -910 | | | | | | | | | | | | -910 |
| | 62937 | 3160 | 53 | 35 | 197 | 1479 | 130 | 1375 | 2450 | 1181 | 269 | 0 | 73287 |
| OTH DIRECT CHARGE | | | | | | | | | | | | | |
| COMPUTER-ODC | | | | | | | | | | | 411 | | 411 |
| OTH DIR CHARGE | 2725 | 5495 | | | | 3137 | 2437 | 675 | 2940 | | | | 17410 |
| | 2725 | 5495 | 0 | 0 | 0 | 3137 | 2437 | 675 | 2940 | 0 | 411 | 0 | 17821 |
| ENERGY | | | | | 65 | | | | 4026 | | | | 4090 |
| CAPITAL | | | | | | | | | | | | | |
| DEPRECIATION | 9 | 1158 | 11 | 299 | 91 | 100 | 7 | 14 | 73 | 20 | | | 1792 |
| AMORTIZATION | | 54 | | | 3 | 3 | | | 13 | | | | 77 |
| RENT | 3 | 126 | | | 8 | 41 | 0 | | 1122 | | 3377 | | 4675 |
| LEASE COSTS | 6 | 1666 | 3 | | 29 | 44 | 4 | | 164 | | | | 1955 |
| TAXES | 249 | 401 | 1 | | 16 | 45 | 2 | 3 | 258 | 7 | | | 982 |
| INSURANCE | | 179 | | 2 | 1 | | | | 110 | | | | 292 |
| | 267 | 3585 | 14 | 301 | 148 | 233 | 13 | 17 | 1792 | 27 | 3377 | 0 | 9663 |
| DIV & CORP ALLOCAT | | | | | | | | | | | | | |
| COMMUNICATIONS | | | | | | | | | | | | | 0 |
| OFFICE SERVICES | | | | | | | | 377 | | | | | 377 |
| LTV CORP ALLOCAT | | | | | | | | 2106 | | | | | 2106 |
| CORP COMMUNICATN | | | | | | | | 1362 | | | | | 1362 |
| WASHINGTON OPNS | | | | | | | | 72 | | | | | 72 |
| PRESIDENT'S POOL | | | | | | | | 540 | | | | | 540 |
| FINANCIAL SERV | | | | | | | | 1991 | | | | | 1991 |
| PROGRAM DEV ADMN | | | | | | | | 135 | | | | | 135 |
| CORP FINANCE | | | | | | | | 423 | | | | | 423 |
| INTERNATION SERV | | | | | | | | 137 | | | | | 137 |
| VOUGHT CORP G&A | | | | | | | | | | | | | 0 |
| ADV TECH CENTER | | | | | | | | | | | | | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7172 | 0 | 0 | 0 | 0 | 7172 |
| | 69967 | 76684 | 5878 | 576 | 2544 | 22540 | 6666 | 14560 | 17697 | 3744 | 7825 | 0 | 228795 |
| MEMO: OTHER ALLOCA | | | | | | | | | | | | | |
| DATA PROCESSING | 447 | 1110 | 74 | 39 | 10 | 341 | 50 | 1150 | 45 | 145 | | | 3419 |
| FACILITIES | 606 | 11876 | 816 | 112 | | 922 | 216 | 234 | | | | | 14802 |
| HUMAN RESOURCES | 166 | 2586 | 232 | 10 | | 523 | 181 | 191 | | | | | 3889 |
| DACOL | | 155 | | | | | | | | | | | 155 |
| STOCK RECORDS | 130 | | | | | | | | | | | | 130 |
| INTER DIVISION | | | | | | | -13 | | | | | | -13 |
| FOREIGN SELLING EX | | | | | | | | -109 | | | | | -109 |
| SCREENED COSTS | | | | | | | | -1501 | | | | | -1501 |
| DEFERRED COSTS | | | | | | | | | | | | | 0 |
| IR&D AND B&P-INCURRED | | | | | | | | 1677 | | | | | 1677 |
| IR&D AND B&P-ALLOCATED | | | | | | | | 5839 | | | | | 5839 |
| ALLOCTNS-COMPUTER | | | | | | | | | | | 321 | | 321 |
| COMPUTER-DIRECT CH | | | | | | | | | | | | 4727 | 4727 |
| | 1349 | 15740 | 1122 | 160 | 10 | 1787 | 433 | 7481 | 45 | 145 | 321 | 4727 | 33326 |
| RATES | | | | | | | | | | | | | |
| OTHER DIRECT CHARG | 2725 | 5495 | 0 | 4 | 4 | 3137 | 2437 | 675 | 2940 | 0 | 0 | 4727 | 22137 |
| DIRECT BASE $ | 63417 | 32641 | 3311 | 122 | 1139 | 11825 | 2560 | NA | 51596 | 51596 | 51596 | NA | NA |
| OVERHEADS $ | 5175 | 54296 | 3690 | 615 | 1424 | 9473 | 2102 | 21366 | 14802 | 3889 | 8146 | NA | NA |
| OVERHEADS RATE % | 8.16 | 166.34 | 111.44 | 505.13 | 125.13 | 80.11 | 82.11 | 10.08 | 28.69 | 7.54 | 15.79 | NA | NA |
| MFG COST ADDITIONS | | | | | | | | 211878 | | | | | NA |
| MFG COST ADJUSTMNT | | | | | | | | 5471 | | | | | |

## DUAL FUNCTION COST MODEL

- THE DUAL FUNCTION COST MODEL IS DERIVED FROM THE TRADITIONAL COST STRUCTURE AND INCLUDES:

  1. POOLS AND COST CENTERS
  2. DIRECT AND INDIRECT COSTS
  3. COST CENTER ALLOCATIONS
  4. OVERHEAD RATES

PRODUCTIVITY

LTV Aerospace and Defense
Vought Aero Products Division

DIVISION DATA (BY ORGANIZATION) YEAR: DATA: SHEET 2 OF 2

| DESCRIPTION | MFG OPER | MATERIAL | QUALITY | ENGRNG | FACILITY | IMOD | VOMC | LOGISTIC | HUM RES | DATA PRO | G&A, FIN | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LABOR** | | | | | | | | | | | | |
| DIRECT BASE | 27057 | 1860 | 4771 | 11825 | | 204 | 3311 | 2560 | | | | 51596 |
| INDIRECT LABOR: | | | | | | | | | | | | |
| SALARIES & WAGES | 7302 | 3375 | 449 | 810 | 4450 | 1003 | 429 | 146 | 1620 | 2820 | 4049 | 26680 |
| OVERTIME | 511 | 85 | 23 | 0 | | 16 | 6 | 1 | 220 | | 141 | 1018 |
| DIRECT ON INDIR | 901 | 40 | 238 | 1240 | | 662 | 39 | 254 | | | | 3390 |
| TRAINING | 312 | 2 | 28 | | | 16 | 21 | | | | | 379 |
| ABSENCES | | | | 126 | | | | 35 | | | | 161 |
| PRODUCTIVITY AND | 503 | 42 | 63 | | | | 67 | | | | | 675 |
| OTHER | | | | | | | | | 16 | | 55 | 71 |
| FRINGE BENEFITS | 16224 | 1749 | 2567 | 3779 | 2090 | 661 | 1938 | 1090 | 672 | 939 | 1076 | 32786 |
| | 53010 | 7169 | 8160 | 17797 | 6540 | 2560 | 5811 | 4086 | 2536 | 3767 | 5321 | 116757 |
| **MATERIAL** | | | | | | | | | | | | |
| DIRECT MATERIAL | | 63417 | | | | | | | | | | 63417 |
| SUPPLIES & EXPENSE: | | | | | | | | | | | | |
| TRAVEL | 99 | 110 | 35 | 96 | | 54 | 3 | 26 | | | 446 | 869 |
| COMMUNICATION | 140 | 129 | 46 | 134 | | 23 | 12 | 66 | 25 | | 130 | 714 |
| FREIGHT NON-PROD | | 34 | | | | | | | | | | 34 |
| TRUCK & TRANSP | | | | | | | | | | | | 0 |
| OFFICE SUPPLIES | 96 | 27 | 15 | 28 | | 6 | 4 | 10 | | | | 186 |
| OFFICE ACCESSORY | | | | 46 | | | | 4 | | | | 50 |
| REPRODUCTION | 137 | 30 | 20 | 52 | | 60 | 4 | 20 | 54 | | 167 | 544 |
| EMPLOYEE RELOC | | | | | | | | | 578 | | | 578 |
| PERISHABLE TOOLS | 925 | | | | | | 14 | | | | | 939 |
| FACTORY ACCESSOR | 14 | 5 | 23 | 30 | | 281 | | | | | | 353 |
| SHOP SUPPLIES | 59 | 8 | 7 | 31 | | | | 0 | | | | 105 |
| OTHER SUPPLIES | 16 | 0 | 5 | 2 | | 0 | | 1 | 12 | | | 37 |
| PUR LAB REL EXP | | | | 1007 | | | | | | | | 1007 |
| OTHER | 700 | 186 | 490 | 53 | 2950 | 101 | 17 | 4 | 310 | 269 | 624 | 5366 |
| CREDITS | | -910 | | | | | | | | | | -910 |
| | 2185 | 63837 | 601 | 1479 | 2950 | 525 | 53 | 130 | 1181 | 269 | 1375 | 73287 |
| **OTH DIRECT CHARGE** | | | | | | | | | | | | |
| COMPUTER-OSC | | | | | | | | | | 412 | | 412 |
| OTH DIR CHARGE | 4432 | 2725 | 1084 | 3137 | 2940 | | | 2437 | | | 675 | 17410 |
| | 4432 | 2725 | 1084 | 3137 | 2940 | 0 | 0 | 2437 | 0 | 412 | 675 | 17821 |
| **ENERGY** | 65 | | | | 4026 | | | | | | | 4090 |
| **CAPITAL** | | | | | | | | | | | | |
| DEPRECIATION | 1305 | 75 | 169 | 100 | 73 | 7 | 11 | 7 | 20 | | 14 | 1791 |
| AMORTIZATION | 53 | 2 | 2 | 5 | 15 | 1 | | | | | | 77 |
| RENT | 9 | 4 | 5 | 41 | 1122 | 119 | | 0 | | 3377 | | 4676 |
| LEASE COSTS | 1498 | 64 | 61 | 44 | 164 | 18 | 3 | 1 | | | | 1853 |
| TAXES | 344 | 269 | 49 | 45 | 258 | 3 | 1 | 2 | 7 | | 3 | 982 |
| INSURANCE | 145 | 10 | 26 | | 110 | 1 | | | | | | 292 |
| | 3333 | 425 | 312 | 235 | 1742 | 149 | 14 | 13 | 27 | 3377 | 17 | 9644 |
| **DIV & CORP ALLOCATIONS** | | | | | | | | | | | | |
| COMMUNICATIONS | | | | | | | | | | | | 0 |
| OFFICE SERVICES | | | | | | | | | | | 377 | 377 |
| LTV CORP ALLOCAT | | | | | | | | | | | 2106 | 2106 |
| CORP COMMUNICATN | | | | | | | | | | | 1362 | 1362 |
| WASHINGTON OPNS | | | | | | | | | | | 92 | 92 |
| PRESIDENT'S PODC | | | | | | | | | | | 540 | 540 |
| FINANCIAL SERV | | | | | | | | | | | 1991 | 1991 |
| PROGRAM DEV ADMN | | | | | | | | | | | 135 | 135 |
| CORP FINANCE | | | | | | | | | | | 423 | 423 |
| INTERNATION SERV | | | | | | | | | | | 139 | 139 |
| VOUGHT CORP [illegible] | | | | | | | | | | | | 0 |
| ADV TECH CENTER | | | | | | | | | | | | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7172 | 7172 |
| | 63045 | 73335 | 10137 | 22640 | 17690 | 3234 | 5878 | 6666 | 3744 | 7025 | 14563 | 228771 |
| **MEMO: OTHER ALLOCATIONS** | | | | | | | | | | | | |
| DATA PROCESSING | 1106 | 495 | 12 | 341 | 45 | | 74 | 50 | 145 | | 1150 | 3419 |
| FACILITIES | 11150 | 937 | 472 | 922 | | 105 | 816 | 216 | | | 234 | 14802 |
| HUMAN RESOURCES | 2032 | 338 | 316 | 523 | | 77 | 732 | 181 | | | 191 | 3889 |
| SACOL | 129 | 11 | 14 | | | | | | | | | 155 |
| STOCK RECORDS | | 130 | | | | | | | | | | 130 |
| INTER DIVISION | | | | | | | | -13 | | | | -13 |
| FOREIGN SELLING EX | | | | | | | | | | | -109 | -109 |
| SCREENED COSTS | | | | | | | | | | | -1501 | -1501 |
| DEFERRED COSTS | | | | | | | | | | | | 0 |
| IR&D AND B&PE-INCURRED | | | | | | | | | | | 1677 | 1677 |
| IR&D AND B&PE-ALLOCATED | | | | | | | | | | | 5839 | 5337 |
| ALLOCTNS-COMPUTER | | | | | | | | | | 321 | | 321 |
| COMPUTER-DIRECT CH | | | | | | | | | | 4727 | | 4727 |
| | 14416 | 1911 | 764 | 1787 | 45 | 182 | 1122 | 453 | 145 | 5049 | 7481 | 33336 |
| **RATES** | | | | | | | | | | | | |
| OTHER DIRECT CHARGE | | | | 3137 | 2940 | | 0 | 2437 | 0 | 0 | 675 | 22137 |
| DIRECT BASE $ | SEE | SEE | SEE | 11825 | 51596 | SEE | 3311 | 2560 | 51596 | 51596 | NA | |
| OVERHEADS $ | SHEET | SHEET | SHEET | 9473 | 14802 | SHEET | 3690 | 2102 | 3889 | 8146 | 21366 | |
| OVERHEADS RATE % | 1 | 1 | 1 | 80.11 | 28.69 | 1 | 111.44 | 82.11 | 7.54 | 15.79 | 9.73 | |
| MFG COST ADDITIONS | | | | | | | | | | | 211970 | |
| MFG COST ADJUSTMNT | | | | | | | | | | | 5471 | |

## DUAL FUNCTION COST MODEL

1. THE MODEL REGROUPS COSTS BY ORGANIZATION INSTEAD OF BY POOLS AND COST CENTERS.

2. THE MODEL PROVIDES DISCRETE DOLLAR COSTS FOR EACH ORGANIZATION WHICH ARE FREE OF DIRECT COSTS, INDIRECT COSTS, AND OVERHEAD RATES.

# APPENDIX B

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